THE CHAIN OF LIFE

LUCRETIA PERRY OSBORN

To

Derick

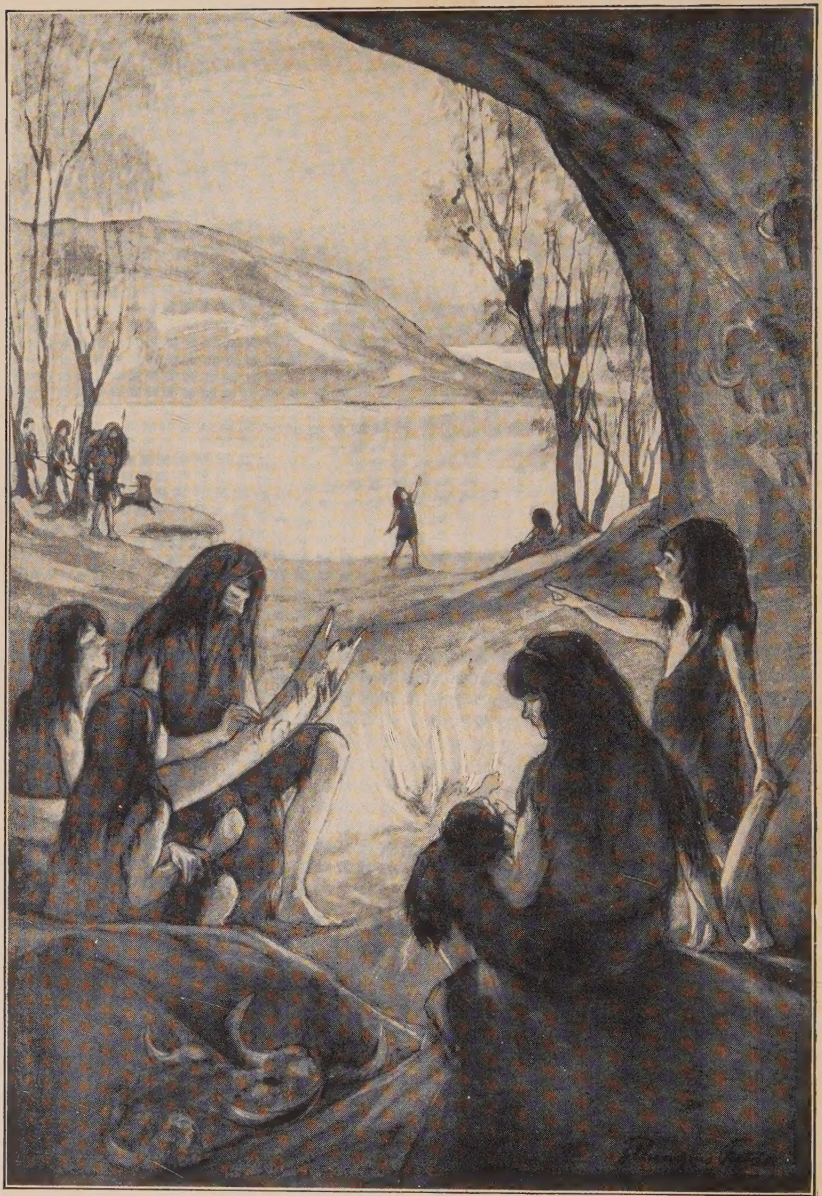
Fitz Eleen Fair

and Loren

James Coe.

1926

THE CHAIN OF LIFE



A cave shelter existing to-day on the Vézère River of France. Restoration of Crô-Magnon family scene and carving of the ivory tusk of a mammoth.

THE CHAIN OF LIFE

BY

LUCRETIA PERRY OSBORN

ILLUSTRATED

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FOREWORD

BY MICHAEL PUPIN

Science is a record of deciphered messages which Nature has communicated to man. The language of Nature and her logic are perfect; human language and logic are only imperfect copies of Nature's divine mode of expression.

> "To him who in the love of Nature holds
> Communion with her visible forms, she speaks
> A various language; . . .
> . . . . . .
> Go forth, under the open sky, and list
> To Nature's teachings. . . ."
>
> (THANATOPSIS)

To him whose ear is trained to listen to Nature's language Nature is reciting an epic poem of things that were when the oldest stars were still young, of things that are to-day, and of things that are hidden in the deepest recesses of endless future. It is an epic which declares the glory of God. No lines in this divine epic thrill the human heart so much as those which tell the story of life. No heavenly gift is so precious as the gift which is called life and which in its highest form endows mortal man with powers to decipher the message of this story. The

meaning of life, the highest of the heavenly gifts, is the greatest of all human questions.

Of the many noble efforts to answer this question by a sincere interpretation of Nature's language and logic none appeals to our sympathies more than those of Henry Fairfield Osborn. The story of his efforts is described in this volume in simple language by one who, as his loving wife and intelligent admirer, watched from the very beginning their growth and development.

AUTHOR'S PREFACE

The records of human life on the earth are written and dated for nearly 6,000 years. Back of that there is a prehistoric period of about 500,000 years, when Man, through the earlier stages of his development, left some signs of his existence, first in implements and fireplaces, later in carvings, paintings, and engravings. Back of that, we have a record of life's development on the earth in the marvellous fossils, which carry life back approximately 100,000,000 years.

This is Evolution, a law as fixed as gravitation; it is no longer a theory. To speak of Evolution as a *theory* is a misuse of terms. The *processes* and methods of Evolution are also more or less perfectly known. The *causes* of Evolution are still only partially known—and this is the only debatable part of Evolution to-day.

This book is planned to make this knowledge accessible to laymen and to students, and to emphasize the fact that, biologically, our ancestors of thousands of years ago are as potent in our individual lives as our Scotch, English, Irish, French, Spanish,

or Italian ancestors who migrated to this country, and whom we may know all about.

A brief history of life on the Earth from the beginning is herein given. Surely, to know of the life behind us is just as important a part of our mental curriculum as many of the prescribed courses in school or university! Prehistory is now being taught, and it is hoped that this book may be of use. Its readers are asked to consider it as they would a book on astronomy, botany, or any of the other sciences; and, as they read of their long line of prehistory, to view it, *not* from the angle of religion or philosophy, but simply as a record of the established facts of astronomy, physics, biology, zoology, and prehistory.

In preparing the text the author has consulted works by the following authorities: Henri Breuil, Marcellin Boule, Miles C. Burkitt, William Wallace Campbell, Chamberlin and Salisbury, Edwin S. Conklin, George Ellery Hale, Richard Lull, Oscar Montelius, Sophus Müller, Lucien Mayet, Jacques de Morgan, Hugo Obermaier, Henry Fairfield Osborn, W. J. Sollas, and Elliot Smith.

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THE CHAIN OF LIFE

invest this profound and far-reaching subject with as much simplicity as we can.

At the outset it seems advisable to sketch briefly the growth, spread, and establishment of the evolutionary idea, for the reader who is to follow its applications in this volume should have some knowledge of its history. Listening to the ignorant utterances of certain bigots who would refuse to admit that science has advanced a step in the past two thousand years, the uninstructed person might be led to believe that Evolution is a recent and particularly dangerous heresy in the world of thought; but the fact is that the evolutionary conception is not a new one. It did not come to certain nineteenth-century thinkers in a blinding flash of revelation or inspiration, although, on the other hand, it was not solidly buttressed with scientific proofs until the nineteenth century. The idea of Evolution, as we hold it, is the fruit of ages of thought and investigation; and for at least twenty-four centuries it has existed in the minds of exceptionally intelligent men as an explanation of life that *might* be true. Since the publication of Darwin's "The Origin of Species," in 1859, there has been no doubt in the minds of the reasonable that it *is* true. That is, there has been no doubt regarding the *law* of Evolution; regarding its *causes* there have been many conflicts of learned opinion, and the final settlement

has not yet been reached. But the law of Evolution now takes its place as a fact beside the law of gravitation, and it is the very foundation of all our thinking about life upon our planet; Darwinism may be called into question, but only those minds most deeply steeped in ignorant prejudice now question Evolution itself, of which Darwinism is but one interpretation.

As is the case when we are tracing down the origins of almost all phases of Western thought and art, we must turn back to Greece to find the beginnings of the evolutionary conception. The Greeks were prone to embark bravely upon theories before they had the facts; they sought to explain the whole universe when it was still a sealed book to them; they were like children gazing at a closed volume and hazarding speculations as to its contents. But they were extremely clever children, and some of their guesses were miracles of intuition.

In the earliest Greek philosophers we encounter an intuition of the evolutionary process; in Aristotle (384–322 B. C.) we find the conception of a single chain of Evolution, but it is unsupported by fact, although the philosopher fully realized that all sound thinking must rest upon a foundation of fact. From the great Greek, whose ideas dominated the Western world for some two thousand years, we may trace the course of the conception down through isolated think-

ers, even through the periods of deepest intellectual darkness, until it receives its scientific documentation in the epoch-making work of Charles Darwin (1809–1882). The curve we follow is not an even one; it rises abruptly and dips as suddenly: in Greece alone we perceive a rise, decline, resurrection, and final fall of the conception; then we note a revival under the natural philosophers of the seventeenth and eighteenth centuries; and finally we encounter the great scientific effort which culminated in Darwin's proofs. That Darwin owed more to his predecessors than is usually realized there can be no doubt; but his was the mind that distilled the very essence of his predecessors' thought, his was the intelligence that comprehended all that was true in speculations earlier than his own, and his was the genius that shed brilliant light upon hitherto dark spaces in the evolutionary science. So it is perhaps excusable that, in the layman's mind, the name of Darwin and the conception of Evolution should now be inseparably linked.

But we have spoken of the fall of the evolutionary conception, following its appearance in Greece, and that phenomenon is worth a passing note. The halt in scientific progress during the Middle Ages was caused by men removing their eyes from the object to be studied—Nature—and riveting their gaze upon previous authorities, Aristotle chief among them.

From such blind discipleship science suffered, much as French poetry suffered from a similar slavishness in the period that followed the towering genius of Racine. But, during the seventeenth and eighteenth centuries, the natural philosophers began to turn their attention to the true source of all knowledge, and to produce treatises that were based directly upon observations of Nature, instead of being merely the echo of some long-dead investigator. Aristotle had insisted that men should study Nature, but men adopted his conclusions rather than his method, and for centuries they turned only to Aristotle himself. It was such investigators as Linnæus (1707–1778) and Cuvier (1769–1832) who, swearing by observation and induction, re-established scientific inquiry upon sound and fruitful ground.

Aristotle's evolutionary ideas were in many instances brilliant conjectures, unsupported by proofs; to-day Evolution rests upon the firm bases of Paleontology, Comparative Anatomy, Embryology and Animal *Distribution*, sciences which were established during the nineteenth century. The founders of modern Evolution had to do battle not merely with the believers in supernatural intervention, but also with those who based evolutionary theories upon traditional or unscientific grounds, thereby bringing discredit upon the whole body of evolutionary thinkers and ex-

posing the fundamental conception to peril. So it is with every great movement in the intellectual world; there are always camp-followers, and even pretended leaders, who, while apparently working for the cause, do it harm rather than good.

One of the great obstacles that the evolutionists had to overcome was the persistent belief, held from Aristotle down to fairly recent times, in Abiogenesis, or the spontaneous creation of life from lifeless matter. We realize how troublesome to the scheme of Evolution this belief might prove when we consider that it could be called upon to explain the higher as well as the lower forms of life. William Harvey (1578–1657) clearly stated the law of Biogenesis (that life comes only from life); but it was not until the latter part of the nineteenth century that his perception was accorded the support of scientific proofs. Nor could embryology, now one of the bases of evolutionary knowledge, contribute its share of proofs until the microscope had been perfected.

But despite our increase of knowledge, despite improvement in the methods and instruments of science, evolutionists have not yet come to the end of their task. Professor Henry Fairfield Osborn has succinctly stated the case, and his words can scarcely be improved upon:

"Our present state of opinion is this: we know to

some extent *how* plants and animals and man evolve; we do not know *why* they evolve. We know, for example, that there has existed a more or less complete chain of beings from monad to man, that the one-toed horse had a four-toed ancestor, that man has descended from an unknown ape-like form somewhere in the Tertiary. We know not only those larger chains of descent, but many of the minute details of these transformations. We do not know their internal causes, for none of the explanations which have in turn been offered during the last hundred years satisfies the demands of observation, of experience, of reason. It is best frankly to acknowledge that the chief causes of the orderly evolution of the germ are still entirely unknown, and that our search must take an entirely fresh start.

"As regards continuous adaptability and fitness of living things, we have a reasonable interpretation of the causes of some of the phenomena of adaptation, but they are the smaller part of the whole. Especially are the chief phenomena of adaptation in the germ; the marvellous and continuous fitness and beauty of form and function remain largely unaccounted for. We have no scientific explanation for those processes of development from within, which Bergson has termed 'l'évolution créatrice,' and for which Driesch has abandoned a natural explanation and assumed

the existence of an *entelechy*, that is, an internal perfecting system."

So we must approach our subject with the realization that our knowledge of it is definitely limited, that there is, as yet, a boundary beyond which we cannot pass; but until we reach that boundary we may study diligently and constantly gather information that may help us some day to continue our journey. The admission of present limitations should not distress us, for such an admission is really an assertion of scientific integrity, and all true knowledge must rest upon honest investigation.

Various explanations of the evolutionary process have been advanced, but all these represent two general schools of belief: the one holds that the controlling causes work upon the organism from without, that the environment moulds the individual and consequently the species; the other holds that the controlling causes are internal, having their origin in the individual germ, and thus affecting the body and finally the environment. The outstanding representative of the first school is Buffon (1707–1788), while the second is represented by Darwin himself and Weismann. Going back of environment and the evolution of form, Weismann insists that the essential problem is the causes of germinal evolution, that the real goal of our search lies in the germ itself—the

germ-plasm, as he calls it; or the "heredity-germ,"* as we shall call it.

But as our knowledge increases, we realize that it is unwise to neglect either environment or germ for the sake of concentrating attention upon the other. Both must be considered; and it is fairly safe to say that the explanation of Evolution which takes into account the greatest number and variety of causes will be nearest the truth. As we search for causes we find ourselves more and more preoccupied with *energy*. As Professor Osborn writes: "Energy appears to be the chief end of life—the first efforts of life work toward the capture of energy, the storage of energy, the release of energy. The earliest adaptations we know of are designed for the capture and storage of energy." Now Bergson has pointed out that philosophers in all ages have made the mistake of attempting to argue from a state of rest to a state of motion, when they should logically begin with motion and thereby proceed to a state of rest which is purely relative; and in the same way naturalists have erred in attempting to argue from the forms of life to life itself, whereas they should reverse the process and think "from energy forward into matter and form,"

*The *germ* is the older and better-known word for that part of the protoplasm which is the bearer of inheritance, hence the term *heredity*-germ. Through the microscope this germ is seen to be highly colored by artificial stains; hence it is known as chromatin, from the Greek χρῶμα = color.

since every form presupposes some shaping energy. The importance of choosing the right line of approach in such questions cannot be overemphasized.

When we seek the energies that give shape to form and result in the outward and visible aspects of Evolution, we find that we can distinguish four main groups or complexes. First of all, there is the Inorganic Environment, the world into which life is originally born, in which the great agents of force are the Sun and Earth, the water and the air. These are the first forces that must affect the Organism; from these it must draw its life; they feed it, and give it form. But soon there is developed the force or energy of the Organism itself, which operates in changing and developing the bodily cells and tissues; and this we may consider as the second moulding and directing energy complex. Then there are the marvellous energies of the Heredity-germ (a convenient name for a substance that is still fraught with mystery for us), the energies that are concentrated in the reproductive cells and insure the succession of generations and the transmission of characteristics. In contemplating the Heredity-germ we are standing on the threshold of life's greatest miracle; it is cause for wonder that we have penetrated the mystery even so far as we have. And the fourth and last group of energies consists of those produced by the Life Envi-

ronment, including the whole scale of life from monad to man.

So, to quote Professor Osborn again, "there are here *four evolutions* of energy rather than one, and the problem of causes is how the four evolutions are adjusted to each other; and especially how the evolution of the germ adjusts itself to that of the inorganic environment and the life environment, and to the temporary evolution of the organism itself."

It is obvious, then, that we must concern ourselves in this book not merely with the fact that the *fit* do survive in nature (which would simply necessitate our tracing the visible progress of Evolution), but also with the question of the origin of fitness. Our task is twofold: we shall trace the development of forms (the effects), and we shall seek to record as much as we now know regarding the evolutionary forces or energies (the causes).

Before beginning to study the Evolution of life upon our planet, it is essential that the reader should firmly realize the position of that planet itself in relation to the rest of the universe as we know it. Such realization is necessary to preserve a sense of proportion. Our Earth is one of eight great planets that move about a central Sun, and with that Sun they form what we call our solar system. But the solar

system is only a unit, a tiny speck, in a vast starry universe, and beyond this universe of ours there are, astronomers assure us, other universes separated from us by inconceivable distances in space, universes perhaps far vaster than our own and in number beyond all calculation.

But, returning to more easily measured distances and more readily conceivable immensities, we note that our Earth is the planet third in distance from our Sun. Between us and the Sun lie Mercury and Venus; beyond us are Mars, Jupiter, Saturn, Uranus, and Neptune. Figures make us realize the vast extent of this solar system with which we are dealing; the mind takes in the fact that our Earth is some 93,000,000 miles from the central source of heat and light, but it nearly halts before the information that Neptune is approximately thirty times as far away from the Sun, or about 2,796,000,000 miles. Yet, let us repeat it, this solar system of which Neptune is a unit is but a speck in our universe, and that universe is probably but one of an infinite number in the infinitude of space.

From the Sun there come not only heat and light, but also the power of gravitation, which holds the eight great planets in their exact and unchanging orbits or pathways, so that year after year, age after age, each planet makes its journey round the sun in

a regular period, the Earth's period being 365 days, or one year. Then, too, our Earth with its Moon, the planet Jupiter with its four moons, the planet Saturn with its rings, and all the other planets, exercise gravi-

The orbits and relative movements of the planets around the sun during the month of January.

tational powers of their own that keep moons and rings revolving around them. It should be remembered, of course, that gravitation is not a force which is exercised simply by a larger body upon a smaller body, but a *mutual action*, by virtue of which every

body in the universe tends toward every other body, to a greater or lesser degree.

The progress of astronomy during recent years has been as remarkable as that of any science: to-day we weigh the stars, measure them, and analyze their component elements. How miraculous it is, for example, that we can measure the diameter of Antares, a glorious reddish star of the first magnitude that is separated from us by 350 "light years" (meaning that light travelling from that star at the rate of 180,000 miles per second requires 350 years to reach our vision upon Earth); how amazing it is to realize that the diameter of this star equals the distance from the Sun's centre to a point in space far beyond Mars, the fourth planet from the Sun. And now Einstein, with his theory of Relativity, which virtually deals with time as a fourth dimension, has immeasurably amplified the vista of astronomers and philosophers.

But, returning to our own planet after this brief flight into space, we immediately ask ourselves questions regarding the origin of the Earth and its age. The answer to the second question is vital to our purposes, while the answer to the first is not so immediately important. Various theories of the Earth's origin have been advanced, and no one theory has yet been justified beyond the shadow of a doubt, but

we are fairly safe in assuming that our planet began as a nebular knot of chemical matter, with a fiery surface such as the Sun has to-day, and an atmosphere which retained the heat of the Sun's rays. The problem of the Earth's age is one with which we have an intense concern. It is obvious that Evolution, as we now conceive it, must have required a very long period of time; and as the evolutionary proofs have multiplied it has gradually become apparent that our Earth must be far older than was supposed a few generations ago. The biologists have demanded a generous allowance of time through which to trace the workings of Evolution, and other scientists have come to their aid with corroborative evidence. It was geology that was first of assistance, but now other sciences are furnishing even more valuable data. The geologists have attempted to estimate the Earth's age, during the Life-Period, by calculating the time required to lay down sediments and accumulate the amount of salt at present found in the sea. But the estimates based upon this procedure vary widely, as we discover when we consider four recent ones all by recognized authorities: the highest is 150,000,000 years and the lowest 70,000,000 years; the mean estimate on the basis of sediments is 90,-000,000 years, and that on the basis of the ocean 95,000,000 years.

THE CHAIN OF LIFE

L. P. OSBORN, 1925

	GEOLOGIC EPOCHS AND MOUNTAIN UPLIFTS		CHAIN OF LIFE 1925 A. D. RECORD HISTORY BACK TO ABOUT 4000 B. C.	Estimates from Thickness of Sediments Years	Estimates from Alteration of Radium Minerals Years
CENOZOIC			PRE-HISTORY		
		Holocene	IRON AGE		
			BRONZE AGE		
			COPPER AGE	500,000	1,000,000
	QUATERNARY AGE OF MAN		NEW STONE AGE		
			OR NEOLITHIC		
			OLD STONE AGE		
		Pleistocene	UPPER PALÆOLITHIC		
			LOWER PALÆOLITHIC		
	Glacial Period (Europe, Asia, America)		DAWN STONE		
			EOLITHIC		
	TERTIARY AGE OF MAMMALS	Pliocene	PRIMATES Ancestors of Man		
	Himalayas Swiss Alps Pyrenees	Miocene Oligocene Eocene			
	Eastern Alps	Palæocene	EVOLUTION OF THE MAMMALS	3,000,000	60,000,000
MESOZOIC		Upper Cretaceous		10,000,000	
	AGE OF REPTILES	Cretaceous			
		Jurassic	DINOSAURS AND BIRDS		180,000,000
	Palisades	Triassic	REPTILES OF THE SEA		
		Permian	EVOLUTION OF THE REPTILES		
	Glacial Period (South Africa)	Carboniferous		25,000,000	
PALÆOZOIC	AGE OF INVERTEBRATES	Devonian	FISHES		
		Silurian			
	Scottish Highlands Adirondacks	Ordivician		25,000,000	450,000,000
		Cambrian	INVERTEBRATES		
ARCHÆOZOIC		Pre-Cambrian	ORIGIN OF LIFE		
	ORIGIN OF LIFE	Algonkian	Moulds, algæ, bacteria Many-Celled Animals (Metazoa)	40,000,000	750,000,000
	Hudson River Highlands	Archæan	Single-Celled Animals (Protozoa)		
	THE EARTH A MOLTEN MASS REVOLVING AROUND THE SUN			100,000,000 Years Ago	1,500,000,000 Years Ago
				approximate estimates	

CHART A

Recent calculations, based upon radio-activity, that is, the accumulation of radium in the rocks, lead us into even more astounding figures. But as William Duane has remarked: "The ages calculated from radio-active data represent the length of time during which we may suppose the chemical elements to have been in more or less mechanical contact with each other. They do not represent the time that has elapsed since the Earth may have reached a state capable of supporting organic life as we now know it."

However, one fact is certain: we need no longer doubt that there has been ample time for Evolution to accomplish its work. Some biologists would demand a period so long as 400,000,000 years, but we may conservatively fix upon 100,000,000 years as the period that has elapsed since the Earth was first ready to support life. This period we have divided into five great geological eras, the sequence of which may be studied in Chart A (page 16). It will be well to keep this chart in view, or at least in mind, during the reading of the following pages, for it offers a fixed chronological scheme that will serve to hold isolated facts in their proper relationships and give unity to the whole.

CHAPTER II

WHERE DID LIFE COME FROM?

WE have now prepared ourselves for one of the most important of all scientific questions: Where did life come from? It is a question that thinking man has asked himself in every age, so we are not surprised when we find the earliest Greek philosophers, ever avid of knowledge and possessed of a profound scientific curiosity, seeking an answer to it. The Greeks confronted Nature and her mysteries boldly; while the East halted at the threshold of the unknown and took refuge in supernatural explanations of facts and events, the Greeks were unwilling to admit that anything is unknowable. The origin of life was one of the subjects that most fascinated them.

With their characteristic passion for law and harmony, they sought a primal substance underlying all the forms of life, from which all the forms of life might have sprung. They noted that ice turns to water, that water turns to steam, that processes of transformation are continually operating in Nature, and so, logically enough, they sought a primal substance of which all life was but a transformation.

The answers to the riddle that they propounded were various. Thales (585 B. C.) claimed that all life sprang from water; Anaximenes (sixth century B. C.) placed his faith in air; Heraclitus (540–475 B. C.) held out for fire; while Empedocles (490–430 B. C.), with an embracing gesture, taught that life has its origin in the four elements of fire and water, earth and air, with love and hate as the moving energies.

All these ideas were, of course, mere guesses, but they were guesses made in accordance with what was then known of Nature; they were logical guesses. Anaximenes argued, for example, that air was transformed by condensation into cloud, that cloud by condensation became water, that water still further condensed became earth, and that the final condensation of earth produced stone. This must have seemed a reasonable and powerful chain of argument to the men of his day.

We, however, must proceed in accordance with very different methods. We have made infinitely numerous discoveries since the days of the Greeks, and perhaps the greatest of all has been the discovery of our own ignorance. This realization serves as a continual check to speculation, but it also affords an assurance that we shall remain upon the ground of facts.

The question that we proposed at the head of this

chapter naturally suggests another query: Can we imagine the Earth devoid of life? We can, but we do not have to imagine it, for near us in space there moves a body that presents a barren surface to us, and through our telescopes we may examine it in considerable detail for the sake of learning what a lifeless planet means. Many of us must have studied the Moon through a telescope on some clear night, and those who have not already done this should avail themselves of the first opportunity, for it is a revealing experience. But do not choose the epoch of full moon for your experiment, for then there will be no shadows on the Moon's face, and the features of the lunar landscape will not appear in the same clear relief which marks them at or near the quarters.

These features consist chiefly of mountains, "seas," and "walled plains," while the whole surface is positively dotted with craters which give the Moon the appearance of a lead sphere that has been shot full of holes. And, indeed, some astronomers claim that it has suffered such a fusillade, from a host of planetesimals; but the more conservative authorities hold that the lunar landscape is the product of volcanic action. The "seas" are misnamed (there is no water on the Moon), for they are really great plains. The principal mountains have been named, and the most

important have been measured, some of them rising above 20,000 feet.

Keeping the Moon in mind, we may picture the lifeless Earth as being littered with volcanic ashes, gravels, sands, and micas, and mixtures of clay and sand, as well as gypsum. We must realize that there were absent at this time all those mineral deposits which are largely the products of decayed plant and animal life, such as the carbonaceous rocks that have been produced by decayed vegetable matter, silicates that are the product of minute organisms, and the like. It is essential to realize, also, that at the time of which we are speaking the Earth was at least partially deprived of sunlight as the result of the gaseous and humid vapors that enveloped it, so the earliest life had to be partly independent of sunlight.

It will be seen, then, that only such organisms could exist as were capable of extracting nourishment directly from the chemical elements contained in the bare rocks and soils of the planet. And the only life forms with which we are familiar that can find nourishment under such conditions are some of the simplest bacteria (minute organisms constituting the most primitive form of vegetable life).

But there was present upon our planet at this time one element favorable to life, and that was water. Regarding the presence of water upon the Earth's

surface there are two principal theories: the first, that water originated in the atmosphere and was precipitated on the Earth in the form of rain or dew when the Earth began to cool; the second, that water, or the greater part of it, came from hot springs inside the Earth itself.

Which of these explanations is the true one does not matter greatly to us; the important fact is that water was present, and water furnished a condition favorable to the creation of life. However, we cannot agree with the early Greek who placed the source of life in the sea, for we know much more of chemistry than he knew, and we are aware that the primordial ocean was lacking in the nitrogenous element that is essential to the existence of protoplasm (primary living matter). The nitrogenous compounds are now derived indirectly from the atmosphere and from the Earth, but during the electrical discharges of thunder-storms they are sometimes derived from the union of nitrogen and oxygen, and it is reasonable to suppose that they were so derived before life existed on the planet. We must bear in mind the fact that the primordial sea, like the land, was devoid of all those elements which are the product of animal and vegetable life, and that it did not then contain the vast accretions of salt that have since been washed into it from the continental rocks.

But there is little doubt that the water on the Earth's surface was rich in chemicals and acids, for it would derive these from the atmosphere.

So, in seeking a location for the origin of life, we must search out a spot or spots where we find both water and the nitrogenous compounds essential to protoplasm, that mysterious living substance which is apparently so simple in its elements but so miraculous in its synthesis. Logically our search leads us to shallow pools of water in which these compounds had been so concentrated as to produce a condition favorable to the origin of protoplasm; and there is now a strong body of scientists to support Professor Osborn when he writes: " . . . it is probable that life originated on the continents, either in the moist crevices of rocks or soils, in the fresh waters of continental pools, or in the slightly saline waters of the bordering primordial seas."

Readers should know that numerous other theories have been advanced in recent years, the most striking suggestion being advanced by Professor Arrhenius and H. E. Richter, who hold that life came to us from some other planet; but the conclusion set forth above is now the one held by the most eminent authorities, and we shall not go far wrong in accepting it. Answering the question of *where* life was born does not, however, answer the question of precisely *how* it was

born, and this second query has been productive of many explanations. For the time being let us avoid this problem which plunges us into the greatest mysteries of biology and chemistry, and marshal the important facts of which we are reasonably certain.

Life probably originated in water, in the circumstances we have indicated. What the first forms of life were we cannot say with definite assurance, but we may assume that they were even more primitive than the simplest bacteria with which we are familiar. The line between inorganic matter and organic matter is an elusive one; but we are convinced that even the first living things were the product of ages of evolution. Once these living units were developed, life had set out upon the highroad of Evolution. Soon, however, it was to come to a great parting of the ways, to the parting between the plant and animal kingdoms.

Here is a tremendous division, indeed, but one not so easily defined as the layman might suppose. What is the difference between a plant and an animal? To the man of "common sense" that must seem an astoundingly easy question to answer, a question scarcely worth the asking: he knows, for example, that he is in no danger of confounding an elephant and a sycamore-tree. But what will he reply if we press him to give us a fundamental difference between the

two forms of life? In all probability he will tell us that an animal has powers of locomotion, while a plant has none. At first glance this seems true enough; but the test of motion is not really a trustworthy one, for there are plants that do move, and there are animals that spend their lives fastened to rocks or reeds, lazily letting the waters bring their food to them.

The distinction is actually a subtle one, for both plants and animals are composed of the same life-substance, which we call protoplasm. Regarding the composition of this protoplasm we shall have something to say in the next chapter; for the present it is enough to know that, both in animals and plants, it is contained in cells, or small vesicles complete in all its elements. In the plant world, the walls of these cells are well-defined and composed of a starchy matter; while in the animal world the cell-walls are exceedingly tenuous and sometimes even non-existent. Every cell, both plant and animal, contains a nucleus, and both sorts of cells reproduce themselves by division, or fission.

Now it is a characteristic of this living substance that it must constantly be absorbing other substances, using them as food, and then rejecting the waste matter, or else it dies. Its growth depends upon the capture and assimilation of food. And in noting

the kinds of food utilized by the plant and animal worlds we are provided with a key to their fundamental differences. We discover that animals must have organic food, while plants are capable of subsisting upon inorganic nourishment; the first feed upon other living things, while the second live on carbon drawn directly from the air and upon mineral salts derived directly from the soil. And the means of taking in nourishment differ, for every animal is equipped with a mouth of some sort, however primitive, and with an apparatus for rejecting waste, while a plant absorbs mineral salts directly through its cell walls, or between little valves, the unused oxygen passing off in the same way. Also, at the outset we note the broad fact that plants absorb carbonic acid and reject oxygen, while animals absorb oxygen and reject carbonic acid.

But even with this fundamental difference of diet held firmly in mind, we are apt to be puzzled as to the proper classification for certain of the lowest forms in the plant and animal worlds. There is, for example, the fly-catching Sundew, which feeds after the fashion of an animal but which is unquestionably a plant; and there is the Springing Monad, or *Heteromita*, which seems to represent the transitional stage between plant and animal. Most interesting of all, perhaps, is *Protococcus*, the tiny green organism which propels

itself by means of two tiny whips, and which has caused endless discussion regarding its identity. But its diet would seem to put it definitely in the plant world, despite its animal-like method of reproduction, and so is the case with *Volvox globator*.

We have not space here, however, to occupy ourselves with these interestingly subtle distinctions. For our purposes the broad difference between the diet of animals and the diet of plants is sufficient. It is enough for us to realize that the plant world evolved from those organisms which were capable of deriving their nourishment directly from inorganic matter contained in the soil and air, while the animal world evolved from those organisms which found it necessary, or possible, to feed upon other organisms.

So there occurred the fundamental split between these two types of living things, a division that grew wider and wider as the ages passed. The plants remained rooted in the soil, or floated in the water without developing sensory or locomotive organs, for Nature does not develop in its creatures capabilities that are not required. Meanwhile the animals were evolving organs that would assist them in their primary activity, their hunt for living food: organs that enabled them to move from one place to another in search of nourishment, over a widening range and with increasing speed; organs of sensitiveness; or-

gans for the reception and digestion of food once it was found; and, of prime importance in a "Nature red in tooth and claw," weapons of offense and defense. The great struggle for survival had commenced, and if it seems unjustifiably cruel according to our humane standards, we should remember that much of the beauty of the animal world—fleetness of foot and grace of movement—is the direct result of the hunted creatures' continued attempt to escape the hunter.

Millions of years were required for even the first phase of animal Evolution, and the end of that phase was marked by the appearance of the fish, a creature perfectly adapted to the environment in which it lives and moves and has its being. Entering upon the second phase, we find ourselves in the presence of land animals; we are on the threshold of the reptile kingdom. We follow the reign of the giant reptiles and observe the obscure rise of the bird and the mammal as the result of conditions produced by the great Ice Age which followed the Carboniferous (or coal-bearing) period. We note the increasing importance of the mammal toward the close of the Late Mesozoic era, and we trace the evolution of mammals down to the dawn of the first Stone Age.

But before we set out upon this lengthy track that will lead us through a period of about 100,000,000

years, let us pause for a while to consider as profitably as we may that ever-baffling question—which we put aside for a moment—of *how* life originated. As we stated earlier, the study of Evolution should begin not with *forms* but with *energies*. And so, before we attempt to trace the Evolution of forms, let us set down the essentials of what we know and what we think regarding the earliest capture of energy for the purposes of life. The unscientific reader may find himself in an unfamiliar field, but once his imagination really grasps the nature and importance of the activities presented to him, he must agree that no field of inquiry could be more fascinating. For our concern is with the mightiest and most moving drama of which we have any knowledge: the first appearance of life upon our planet, some hundred million years ago.

CHAPTER III

HOW DID LIFE ORIGINATE?

WHEN we come to consider the origin of life upon the Earth, we find that first of all we must contemplate the Sun, and we realize that the sun-worshippers of old were symbolically if not theologically right in their selection of a deity. For it was the heat, light and other energies given out by the Sun that played determining rôles in the development of the earliest earthly life, and the action of those energies still continues. It may be said, then, that in a large measure we owe to the Sun all we have been, all we are, and all we may become.

In that dim age of which we are now speaking, the solar heat and light were probably more intense than they are at present; but, on the other hand, the atmosphere was filled with denser clouds, so that far more sunlight was turned back from the Earth than is the case to-day. Taking all the factors into consideration, scientists have concluded that the temperature was then approximately the same as our mean temperature, while the sunlight was less intense and less continuous than that with which we are familiar.

However, our determination to do full justice to the life-giving powers of the Sun must not lead us to neglect the claims of the Earth itself, for the heat given out by our planet played its part in furnishing energy to the first life forms, just as did the solar heat. We know that air, earth, and water contained the chemical elements essential to life—the elements were there, awaiting the great miracle. What were those elements? And how did they combine to produce living matter? Let us first consider the composition of protoplasm, for it is with protoplasm that we must constantly deal.

Remembering that the chemist can only analyze life into its *dead* elements, and that he has not yet penetrated the ultimate mystery of living matter, we find that living organisms contain some twenty-nine of the eighty-two or more elements that scientists have discovered. Some of these elements are invariably present in every living thing, others appear less frequently, but each performs its very definite service or function. Listing the essential elements, we note that they are hydrogen, carbon, oxygen, nitrogen, phosphorus, sulphur, potassium, magnesium, calcium, iron, and, probably, sodium, chlorine, and silicon. Less frequently we find iodine, which is essential in all the higher animals; manganese, found in some plants and in small proportions in

animals; bromine, present in marine plants and insignificantly in animals; and fluorine, which appears in a few plants, and which is a constituent of animal bones and teeth. The rare elements, such as aluminum, barium, and copper, form a fairly long list that we need not consider in detail. It will be more profitable to devote our attention to the chief functions of the principal elements.

Ahead of all their fellows there stands a group that we might well name the Big Four—hydrogen, carbon, oxygen, and nitrogen—for these play the dominating rôles in all organic processes. Hydrogen enters, by means of its ions, into animal respiration and digestion, and with oxygen it forms water, which is the chief constituent of living substance. Carbon is dominant in all protoplasm—so strikingly so that Ernst Haeckel would name it the base of all life—and its chief function consists in uniting with oxygen and tearing it away from neighboring elements; it is an important part of all plant foods, also of cell walls, and composes one-half of the dry weight of any plant. Oxygen is virtually omnipresent, for two-thirds of all animal tissue and one-half of the earth's crust are composed of it. Forever circulating in the tissues, it acts in the release of energy, is involved in all heat production and mechanical work, and directly affects cellular division and growth. Nitrogen, which was

present on the primordial earth, is one of the three most important structural materials—sharing this distinction with hydrogen and oxygen—and it combines with sulphur and carbon to form protein, one of the principal foods of the plant and animal worlds.

Turning away from the Big Four, we note that phosphorus is a most important element, which performs several services. In the form of calcium and magnesium phosphates it serves as a building-material for the bony structure of animals; it is essential to the nucleus of every cell, and figures largely in the germ-plasm which we call the Heredity-germ; it appears in the structure of nerves and brain; and it helps maintain uniformity of reaction in the blood.

Sulphur, uniting with the Big Four, forms the proteins that are so essential to plant and animal life; it also serves as a defensive agency against bacterial poisons.

Potassium is an essential in all living tissue, being of particular service in building up complex compounds, while magnesium is necessary to chlorophyll, that green coloring matter in plants of which we shall have more to say later. Calcium enters into a great number of animal skeletons; iron is essential to the production of chlorophyll, while not contained in it,

and also acts as a carrier of oxygen from the lungs to the tissues of the higher animals.

Now that we know something of the nature of protoplasm, we have some knowledge of the functions performed by the elements that it contains. But there still remains the fundamental question: How did these elements combine to produce life? Here is one of the greatest, or really the greatest, of scientific questions; but to-day scientists are prepared to advance fairly accurate answers. We have seen *where* the life elements grouped themselves; and we have every reason to believe that they grouped themselves one by one, and that these groups were formed, as opposed to the crystalloid, in the colloidal state of matter—the glue-like state, which is peculiarly favorable to the action, reaction, and interaction of chemical elements. These elements gathered together, one by one, gradually forming individual or organic unities; every added element brought a new contribution to the whole. Interaction between the elemental groups was developed and the evolution of function paralleled the evolution of those internal messengers which operate between these groups within a single organism. As these messengers, or *catalyzers*, became more efficient, the single-celled organism evolved gradually into the trillion-celled organism. And we may assume that from the very beginning the law of

Natural Selection was in operation, that the fitness of two competing individuals was rigorously tested, and that victory went to the one with the most efficient actions, reactions, and interactions.

The transition from the lifeless to the living world, from inorganic to organic matter, was marked by the conversion of latent energy into food. The chemicals in the earth, air, and water are transformed from potential energies into the moving forces of existence. We have every reason to believe that the first activity of living matter was the capture and transformation of the *electric energy* of the Sun. First of all came the transformation, the utilization, of *heat* energy by bacteria, which drew life directly from the heat of Earth and Sun. The transformation of *light* energy came much later, when chlorophyll was developed as an agency of capture. The *green coloring matter* of plants, named *chlorophyll*, is one of the most remarkable and important factors with which we have to deal in the organic world, for it enables plants to appropriate to their own use the radiant energy of the Sun. Reducing its chemical function to the simplest possible terms, we may say that it takes carbonic acid from the atmosphere, separates it into carbon and oxygen, rejects the oxygen, and makes the carbon enter into the plants themselves. But this operation can be performed only in the pres-

ence of sunlight. And we know now that sunshine, combining solar heat and light, is a constantly operating source of organic energy.

The proof that chlorophyll, the green coloring matter of plants, absorbs a part of sunlight is easy. Pass a beam through a prism, and it divides into seven colors; pass it first through a green leaf, and some of these colors fail to show through the leaf, especially red, blue, and violet. Although chlorophyll is the peculiar possession of plants, its miracles do not benefit the plant world alone, for the animal world is primarily dependent for its nourishment upon chlorophyll-bearing plants; so this remarkable agency really functions for the sake of all living matter. And chlorophyll performs another service, for the accumulation of carbon dioxide in the atmosphere would finally destroy all animal life were it not absorbed by photosyntheses, *i. e.*, the combining action of light. If we follow the circle of the physico-chemical process, we see that solar energy is transformed by plants into the potential energy of carbon, hydrogen, and oxygen compounds, thereafter converted by the animal into motion and heat, and then expended or dissipated. After this the process repeats itself; so we are contemplating a cycle that illustrates both the conservation and degradation of energy.

Once we have noted the combination of chemical

elements essential to life, we find ourselves concerned with the actions and reactions of elements and electrolytic compounds, and with the interaction of various groups of elements within a single organism. To *action* and *reaction* we have given the name of *ionization*, while *interaction* is called *catalysis*. Here we are approaching ground that may be difficult for the non-scientific reader; but it will be less difficult if he will hold firmly to the idea that the mechanism of life really consists in the building up and breaking down of complex and unstable molecular groups or agglomerations. This dual process is known as metabolism.* As one writer phrases it: "The fundamental fact of life is the metabolism of living substance, which is continually and spontaneously undergoing decomposition, and building itself up anew with the help of the food-substances it takes in." And another scientist, speaking of the molecular interchange which marks all life, says: "It is a series of fermentations and thus also a series of catalytic actions and interactions, a catalytic action being a molecular change or series of chemical changes brought about by the presence of some substance which apparently takes no part in the chemical reactions, but only acts as the medium by which the process is set going and also carried out."

* Renewal or change of function in protoplasm.

Seeking the simplest terms of explanation, we may say that ionization is primarily due to electrolysis, or electrolytic dissociation, whereby various substances are chemically decomposed and made to give off streams of electrically charged particles that are known as ions. These ions are both positive and negative, metallic elements giving off the former sort, non-metallic elements being responsible for the latter. The molecules are constantly breaking up to form ions, and the ions are constantly recombining to form molecules; so we see that electric activity in all living matter is unceasing.

Catalysis, on the other hand, is the action of a substance (known as a catalyzer) which changes the speed of any chemical reaction, without itself being used up by that reaction. Catalysis, which was originally noted as a function of inorganic matter, underlies the great series of functions in the organic world which depend upon the interaction between different groups of elements.

It is obvious that the harmony of a complex organism comprising many parts can be maintained only by interaction between those parts, and this interaction is largely effected by means of "chemical messengers" (catalyzers) that are set in motion as the result of actions and reactions. Thus an action upon one part of the organism produces an interaction at some distant point, and we see that the work of these mes-

sengers consists in correlating and co-ordinating the various activities of the complex organism. We do not know all about them as yet, but we are familiar with a few of their forms.

The simplest that we know are the chemical messengers which are sent out as the result of single chemical reactions. "For example, the carbon dioxide (CO_2) liberated in the cell by the reactions of respiration acts at a distance on other portions of the cell and of the organism. Thus every cell of the body furnishes in the carbon dioxide which it eliminates a chemical messenger, since under normal conditions the carbon dioxide of the blood is one of the chief regulators of the respiratory centre, influencing this centre by virtue of its acidic properties."

Then there are the organic catalyzers that are called *enzymes*, probably of a protein composition, which are continually active in forming unstable chemical compounds that are subsequently decomposed with great rapidity, leaving the catalyzer itself unimpaired in efficacy and ready to repeat the process. The enzymes are highly selective in their operations, because, as they are themselves organic compounds, they exercise varying effects upon the compounds which they encounter in the fluid circulation of the organism. In fact their action justifies the predication of Huxley that it would become possible "to introduce into the economy a molecular mechanism

which, like a cunningly contrived torpedo, shall find its way to some particular group of living elements and cause an explosion among them, leaving the rest untouched." Typical enzymes are: *ptyalin* in saliva, which splits starch into its sugar elements; *pepsin*, which breaks down proteins in the stomach; and *lipsac*, which splits up fats in various parts of the body.

Among the catalyzers we must number the antibodies, or agents of immunity which act as antitoxins against such diseases as diphtheria and tetanus; but perhaps the most interesting of all are the internal secretions which pass directly from the endocrine, or ductless, glands into the blood stream, and which stimulate or retard the activity of other organs. The study of these secretions is one of the more recent steps of science, but to-day even the layman is aware of the important part that these secretions play in the vital functions. He knows that the whole bodily structure is affected by the chemical messengers that are sent out by these glands. He hears much of the thyroid gland, for example, and he learns that the degeneration of this gland has the most startling effects, that it affects the bodily weight, the appearance of the skin, the hair, and the mind itself. Again, he learns that an affection of the pituitary gland may result in the arrested growth of certain organs of the body. Every day scientists are adding to our knowl-

edge of the ductless glands, and their investigations give promise of amazing revelations to be made by the science of biochemistry.

All this consideration of interaction within the organism leads us quite naturally to the problem of the much more difficult interaction that must take place between individual development and race development. What is the process of interaction between body protoplasm and germ-plasm or heredity chromatin? Science stands to-day upon the threshold of that problem, but only on the threshold. As Professor Osborn phrases it: "The eternal question remains, How do these energy phenomena which govern the life, form, and function of the organism interact with the supposed latent and potential energy phenomena of the heredity germ-cells?" And he tells us that the question can be answered only by future experimentation. "There is no proof at present." But he is hopeful that continued study in "the mysterious field of interaction" will lead us to a solution. Meanwhile, with some slight understanding of the physicochemical activities which characterize all living matter, let us clarify our view of the subject by descending to a few specific examples as they are afforded us by certain of the lower forms of life.

CHAPTER IV

THE BEGINNING OF EVOLUTION

BACTERIA are the lowest organisms with which we are familiar, and they are the most primitive with which we have to deal in our study of life. We know that neither plants nor animals could live in a world devoid of bacteria, and we are sure that there was a long period during which these minute vegetable organisms prepared the ground for the evolution of plant and animal life; but we must not make the mistake of assuming that they were the "first living things," or that they were a direct and immediate product of inorganic matter. Obviously there was a stage of life even earlier than the bacterial, a stage in which protoplasm had not yet divided into the definite units that we call cells, when living forms were even simpler than the simplest that we know; for we have every reason to believe that the development of organic from inorganic matter was a process that required ages to accomplish. All we can safely say, then, is that these organisms are the closest of all existing forms to those primordial forms which were first capable of transforming non-living materials into living matter. They represent for us a phase of evo-

lution lying between the hypothetical, pre-cellular phase and the phase of definite cell-structure as manifested by the lowest plants.

Our knowledge of bacteria, it should be noted, is largely the result of chemical and functional research rather than of structural observation, for many of these organisms lie beyond the range of microscopic vision. An idea of their size may be gained by the remark of one botanist who has said: "Such forms would have many times more room in a drop of water than a whale would find in New York harbor." So, while we know little of their *form* in many instances, we are well acquainted with their methods of capturing, storing, and releasing *energy*. This knowledge represents one of the latest steps of science, for so late as the middle of the nineteenth century these tiny forms were looked upon as microscopic curiosities that were remarkable chiefly for their infinitesimal size and their powers of motion. They were then accorded no attention in the study of the chain of life, nor was their effect upon living organisms considered, and they were lumped with all other minute organisms, under the name of "animalcules."

Grouping them according to their methods of obtaining food, we find that bacteria fall into three general classes. There are those that we call *prototrophic*, or "primitive feeders," which are capable of

deriving their nourishment directly from the lifeless chemical compounds found in earth and air and water; there are the *metatrophic*, which live upon organic substances that they obtain from the remains of dead organisms or from the surface of other organic bodies; and there are the *paratrophic*, real parasites, which inhabit living organisms and flourish upon their blood, juice or tissue.

The most ancient of these classes is, obviously, the first; for this class alone is capable of existence upon a planet devoid of other organisms. It was this class that, almost literally, paved the way for the future evolution of living forms. The importance of bacteria to plant and animal life is apparent when we learn that there are certain bacteria, which we call *nitrogen-fixing*, that exist in the soil and are capable of combining inert free nitrogen with other elements into compounds that may be assimilated as food by plants. The supply of nitrogen thus furnished for plant life is inexhaustible, and the plants thus fed serve in turn as food for animals. So the nitrogen-fixing bacteria, working obscurely, play a rôle of prime importance in life's drama.

We find upon our Earth to-day bacteria so primitive that they appear to be survivors from Archæozoic time (see Chart A, p. 16) and when we study them we discover that each bacterial cell is a tiny

chemical laboratory in which oxidizing catalyzers are busily at work. And if we consider the varieties of existing bacteria we are confronted with a series of increasingly complex chemical phases, while we note the parallelism of the chemical and structural evolutions of the organism. The most primitive forms show us a protoplasm that is uniform and virtually unprotected; from this we may trace the evolution, step by step, in the direction of a typical cellular form, complete with cell wall and nucleus of chromatin; while along the way we have ample proof that the chemical reactions of bacteria are analogous to those of the higher plants and animals. It should be stated that at present biologists are not unanimously agreed that any bacteria possess a nucleus which is similar to that of the higher plants; but they are agreed as to the presence of chromatin-granules which may be considered as representing a rudimentary nucleus. Regarding chromatin (Heredity-germ plasm) we shall be more explicit in a moment.

Among the chemical elements which enter into bacterial life are sodium, potassium, phosphorus, magnesium, sulphur, calcium, chlorine, nitrogen, and carbon. The activities made possible by these elements are carried on best in the absence of sunshine, for most bacteria are light-avoiding and heat-loving, depending for existence on solar and earthly heat.

Within the cell laboratory of the bacteria we discover that the principal chemical energies of the organic world are in operation. The organism is capable of storing food in the forms of protein and carbon energy; it has a colloidal, or glue-like, cell interior adapted to chemical actions and reactions of metallic on non-metallic elements; and it also possesses catalytic messengers or enzymes, the enzymes being of three kinds. So we find that even the lowly bacteria, beyond the limit of microscopic vision, are really miraculous organisms, capable of activities that are a foreshadowing of the more complicated processes of plant and animal life.

There is no need to dwell here upon the rôle that bacteria play in the formation of the earth's crust, although that rôle is an important one; and we shall not discuss the classes of bacteria other than the "primitive feeders," for they are not relevant to our purpose. Obviously they represent a later phase of life than that with which we wish to deal here. After the appearance of chlorophyllic (green leaf) plants, there evolved a group of parasitic bacteria which captured nitrogen from the atmosphere through *symbiosis* (life association) with plants, and which derived their carbon from plant carbohydrates instead of from lifeless compounds. A still later development is represented by the *paratrophic* bacteria, which, as

we have seen, are true parasites living within other organisms. But our concern is not with these. We have finished with the bacteria when we have pointed out their adaptability to life upon an otherwise lifeless world, when we have designated them as the first exhibit in the series of life forms we shall present. And before continuing with this series, it may be profitable to turn aside for a moment to discuss that *chromatin*, or visible substance of the Heredity-germ, to which we have already occasionally referred.

The "colorable nuclear matter," known as chromatin (Heredity germ-plasm), which is virtually identical with *nuclein*, and which receives its name from its affinity for certain dyes, such as carmine, logwood, and various aniline stains, is one essential constituent of the cell nucleus. When greatly magnified by the microscope the chromatin is the most conspicuous feature of the cell. Some biologists, as we have noted, hold that bacteria possess neither nucleus nor chromatin; but in this regard we shall quote Professor Edward Alfred Minchin, who writes: "It seems justifiable at present to believe, until the contrary has been proved, that all organisms, however primitive, contain chromatin in some form: first, because this substance has always been found when suitable methods for its detection have been employed; secondly, because it has been shown experimentally,

by cutting up small organisms, such as Amœba, that enucleated fragments of protoplasm are unable to maintain their continued existence as living bodies; and thirdly, because modern research has shown the chromatin to be of very great, perhaps of fundamental, importance in regulating the vital processes of the cell, and so determining the specific characters of the organism, a property which enables the chromatin to act as the vehicle of heredity and to transmit the characters of the parent to offspring. In the present state of our knowledge, therefore, the peculiar chromatin-granules must be regarded as an integral part, perhaps even the most essentially and primarily important portion, of the living substance." Here we find a suggestion of the tremendous rôle assigned to the Heredity-germ (chromatin) by recent scientific investigators.

The maintenance of specific form in an individual organism, despite the constant intake of food and expenditure of energy, despite the constantly changing substance of which the organism is composed, is a remarkable fact. But still more amazing is the perpetuation of organic form through generations; and for this the chromatin, or Heredity-germ, is now held responsible. In Professor Osborn's words: "As protoplasm is now known to be the *expression*, so chromatin is now known to be the *seat* of heredity."

Analysis shows that this amazing substance is infinitely more complex, in its molecular and atomic composition, than any other form of matter or energy with which we are familiar. Observing its method of reproduction, we see that the chromatin divides itself precisely in half at every cell-division; but we also note the surprising fact that its bulk is constant in successive generations, so we learn that it has the faculty of doubling its bulk between cell-divisions. This faculty makes certain that every new cell will be possessed of its necessary chromatin mass.

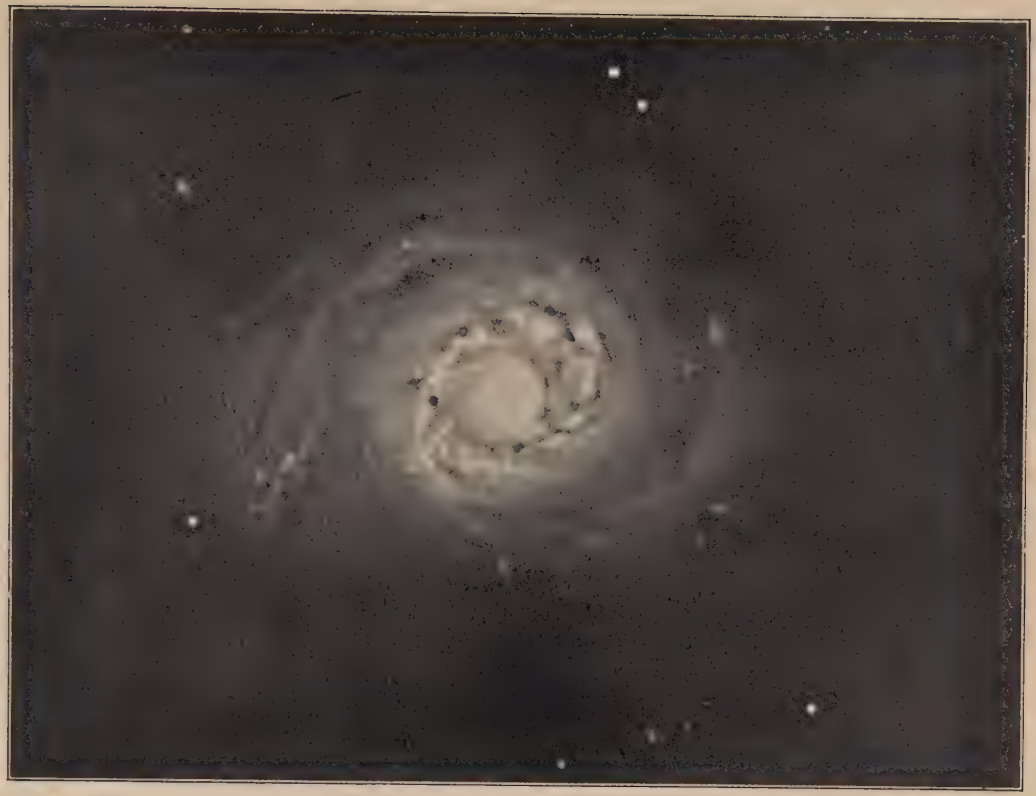
As to the relative antiquity of protoplasm and chromatin there have been many discussions, and these have so far been unfruitful of conclusions; but if we accept chromatin as the *seat* of heredity, and protoplasm as the *expression*, we are led by logic to conclude that the two have been coexistent from the beginning of life. This surely is the view that accords best with the sum of our present knowledge.

In concluding this little side-excursion into the properties of the heredity-chromatin, we cannot do better than to quote one more passage from Professor Osborn, for here we shall find a succinct statement of generalizations drawn from minute investigations. It should serve to clarify our whole view of the matter. Professor Osborn writes:

"It would appear, according to this interpretation,

that the continuity of life since it first appeared in Archæozoic time is the continuity of the physico-chemical energies of the chromatin; the development of the individual life is an unfolding of the energies taken within the body under the directing agency of the chromatin; and the evolution of life is essentially the evolution of the chromatin energies. It is in the inconceivable physico-chemical complexity of the microscopic specks of chromatin that life presents its most marked contrast to any of the phenomena observed within the lifeless world."

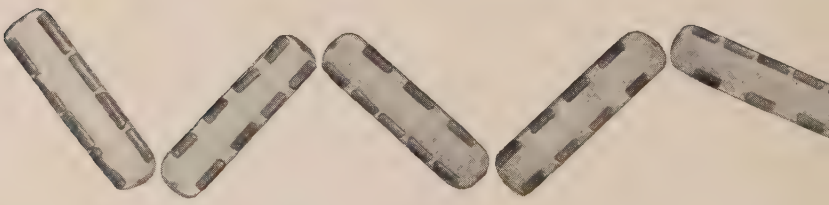
Returning to the main course of our narrative, we find that the appearance of the *algæ* (primitive water-plants) marks the second great phase in the evolution of earthly life. Here, for the first time, we encounter that remarkable agency chlorophyll (green coloring in leaf plants), with which we have dealt at some length; and its advent is a phenomenon of prime importance in the history of Evolution. No longer need organisms depend for food upon the chemicals found in bare rocks, and soils, and water; now they are so equipped that they may draw carbon directly from the atmosphere. A great revolution, if we may speak rather loosely, has taken place in the plant world. Heat is no longer the prime moving factor of existence: the rays of the Sun itself have been harnessed to the car of life.



A faint double-branched spiral nebula (Pease).

A

B



C

Models of single-celled plants, Protophyta, in colonies (*A*, *Asterionella*) and single (*Synedra*, and *C*, *Diatoma*). *American Museum of Natural History.*

It is true that the most primitive, or "blue-green algæ,"—which are immediately above the bacteria —do not give evidence of possessing distinct particles of chlorophyll, but we know that chlorophyll is present in them; and in the true algæ (green) the substance is clearly defined. The lowest algæ are found widely distributed, in the salt sea, in fresh water, in moist earth, on damp rocks, and in the bark of trees; while the higher class, or the "green" variety, has played an important part in the formation of the earth's crust, recent investigators crediting this class with the building of rocks and reefs, and particularly the ancient, pre-Cambrian limestones that may date back more than sixty million years. These green algæ we may regard as "the most primitive survivors of a line from which the higher land plants have been derived."

There are other varieties of these lowly plants besides the two that we have mentioned, and they afford the botanist a fascinating, profitable field of study, but we cannot pause to dwell upon them here. In our survey we have time to consider the algæ only as a link between the bacteria and the higher plants, —though a very notable link, let us insist, for we must not forget the importance of their chlorophyll. From them we turn to the Protozoa, the most primitive of all *animal* forms.

The single-celled animals which we group under the name of Protozoa are so close to the most primitive vegetable organisms that we might well confuse them with the latter, were it not for that most important item of diet to which we have previously called attention. We know that the Protozoa are true animals because they are dependent upon other living organisms for their nourishment. They are incapable of deriving their food from the most primitive sources—earth, air, and water—they must take it second-hand, in pre-digested form, if we may so phrase it. And so we find them feeding upon the bacteria and the algæ which preceded them upon the earth and which are capable of building up inorganic matter into living substance. In a sense then the Protozoa may be considered as the first *hunters*. Their appearance marks a new stage of existence.

Precisely when these unicellular (or, as some biologists would prefer, *non-cellular*) animals appeared, we are not certain. We know that they feed upon bacteria and that they serve to limit the activity of nitrifying bacteria in the soil, so it is possible that they made their appearance during the bacterial phase of existence. But it is also possible that they followed the chlorophyllic algæ, with which the surface of the primordial seas once swarmed, for the surviving representatives of those early vegetable organisms are

now the principal food of the swimming and floating Protozoan types.

In any event, we are clear as to the place of the Protozoa in the history that we are following. They represent the first organisms which were unable to exist apart from other living organisms. So far as structure goes, their class distinction lies in the fact that they are single-celled, the cell being complete in itself and capable of maintaining an individual existence, granted the proper environment. In the Metazoa (many-celled animals) on the other hand, the cells are adapted to the performance of various functions and are mutually interdependent, no one being capable of existence apart from the others. This is the line by which zoologists now divide the entire animal kingdom into the two great sub-kingdoms of Protozoa and Metazoa. Usually the single-celled organisms are simpler, both structurally and functionally, than the many-celled organisms; but this is not an invariable rule, for we discover that the most complex Protozoa are as specialized in their organization as the simplest of the Metazoa. The fundamental difference, then, is that in one case a single cell does the whole work of the individual, while in the other case that work is performed by the co-operation of a number of cells.

As regards *shape*, the Protozoa vary. The *Amœba*

type, in which the protoplasm is unprotected by a membrane or bodily envelope, is continually changing its form as the result of movement; but the greater number of Protozoa are given a definite form by virtue of a containing membrane or cuticle. This form naturally varies in the different species in accordance with their different habits of existence. So we find that the sedentary, or virtually immobile, types are usually round, while the swimmers are ovoid. In connection with this phase of the subject, the reader should be informed that the majority of these organisms are of microscopic size.

But more important than the question of form is the question of function. We observe that the most primitive animals are distinguished by their powers of locomotion, and that they share with plants the habit of turning toward, or moving toward, the Sun. But animals, even the most primitive, exhibit individual powers of which plants are not possessed. In the animal we first encounter what has been termed "a conscious aspect of behavior," as evidenced by individual initiation and experimentation. In this connection we may quote a passage from Professor Osborn, dealing with the investigations and conclusions of H. S. Jennings.

"In his remarkable studies," writes Professor Osborn, "this author traces the genesis of animal be-

havior to reaction and trial. Thus the behavior of organisms is of such a character as to provide for its own development. Through the principle of the production of varied movements and that of the resolution of one physiological state into another, anything that is possible is tried and anything that turns out to be advantageous is held and made permanent. Thus the sub-psychic stages when they evolve into the higher stages give us the rudiments of discrimination, of choice, of attention, of desire for food, of sensitiveness to pain, and also give us the foundation of the psychic properties of habit, of memory, and of consciousness. These profound and extremely ancient powers of animal life exert indirectly a *creative influence* on animal form, whether we adopt the Lamarckian or Darwinian explanation of the origin of animal form, or find elements of truth in both explanations. The reason is that choice, discrimination, attention, desire for food, and other psychic powers are constantly acting upon individual development and directing its course. Such action in turn controls the habits and migrations of animals, which finally influence the laws of *adaptive radiation* and of selection. In this indirect way these psychic powers are creative of new form and new function."

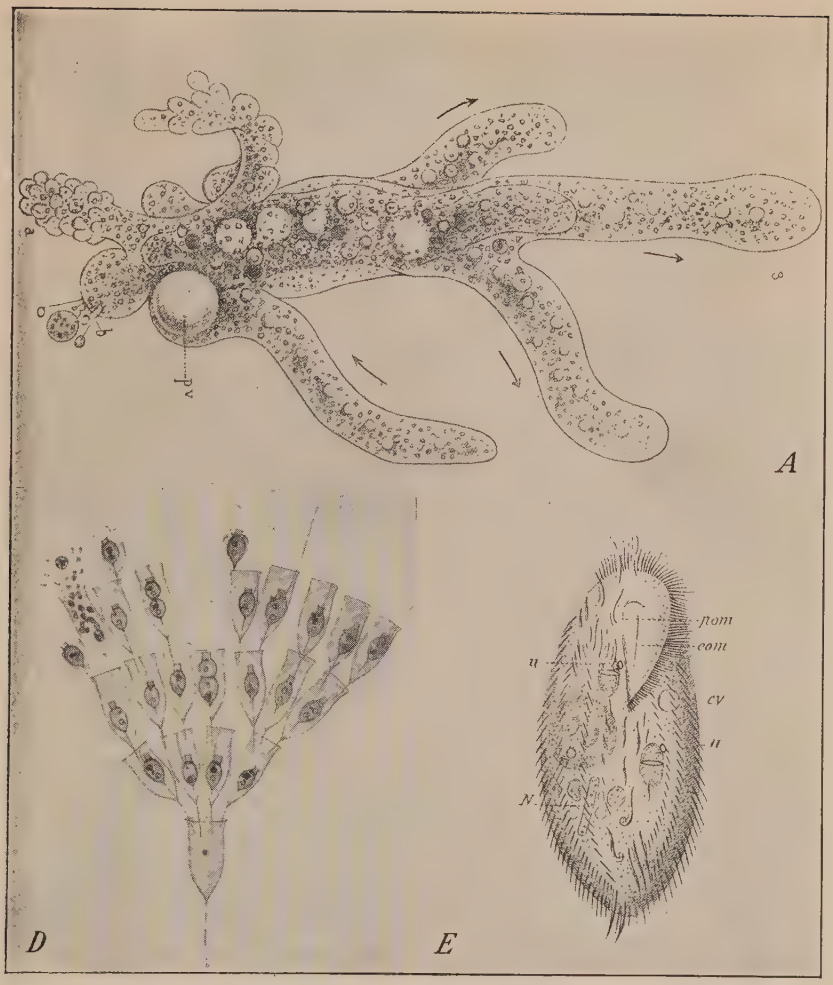
Adaptive radiation is defined by Professor Osborn as "the development of widely divergent forms in

animals ancestrally of the same stock or of related stocks, as a result of bodily adaptation to widely different environments."

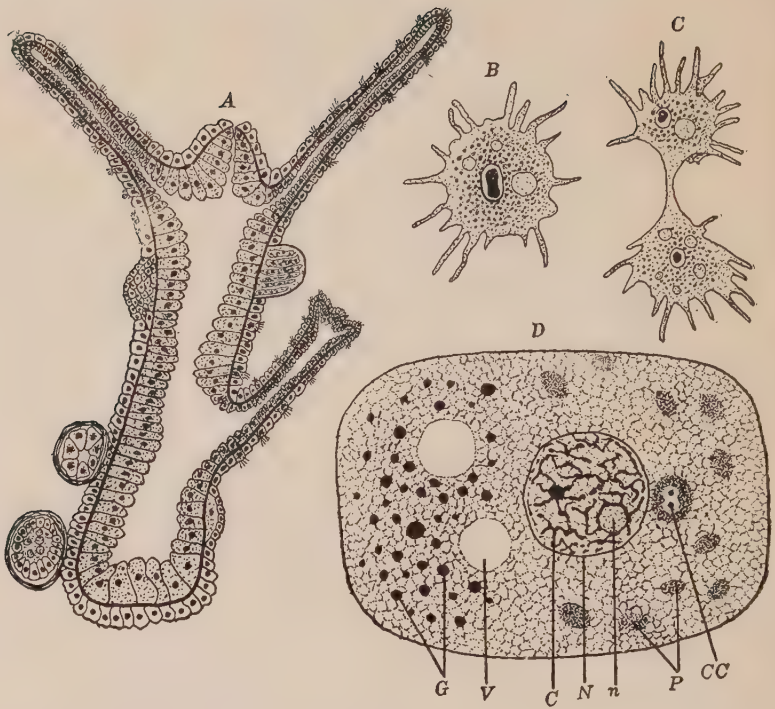
So, even in these lowest animal forms, we find potentialities of incalculable importance.

Tracing the evolutionary stages represented by the Protozoa, we find that the most primitive is that of a simple cell, composed of a small amount of Protoplasm, which contains a nucleus that holds the heredity-germ. After this come the creeping semi-terrestrial forms, in which the bulk of the Protoplasm has increased tremendously. The creeping types are unprotected by a containing membrane; but when we reach the floating varieties we discover a definite skeletal development, and the remains of these microscopic skeletons are found to be a considerable factor in earth-building. In still another form we note that the organism has developed flagellate, or whip-like, organs of locomotion and food-capture. But the highest of all these single-celled types are the *Ciliata*, which are organized for the performance of all the vital functions that the Metazoa perform through the co-operation of their various cells.

Considering the chemical nature of Protozoan life, we observe that there is a continual and regulated interactivity between the gelatinous and crystalloid substances of which the organism is composed. And

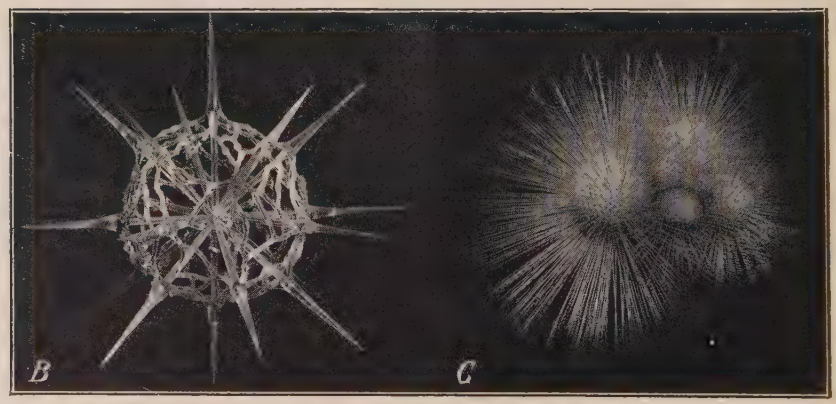


A colony of single-celled animals. *A, Amœba proteus*, one of the soft, jelly-like organisms which rank among the simplest known animals. Magnified two hundred times life size. *D*, a colony of flagellates or Mastigophora, distinguished by whip-like prolongations which serve chiefly for locomotion. Magnified two hundred and eighty-five times life size. *E*, a typical ciliate, one of the most highly organized single-celled forms, distinguished by fine hair-like cilia used for locomotion and capture of food.



From Pirsson & Schuchert's "Textbook of Geology," by courtesy of Ginn & Company.

Hydra and Amœba, single and many-celled animals. *A*, the fresh-water *Hydra* (left), ideal type of the simplest form of many-celled organism. *B*, *C*, *D*, the *Amœba* (right), ideal type of the single-celled organism.



Skeletons of typical single-celled animals. *B*, *Radiolaria*. *C*, *Foraminifera*. These organisms float on the surface of the sea. *American Museum of Natural History.*

we find the familiar chemical messengers, or catalyzers, playing a controlling part in these activities. Reproduction is accomplished through cell-division that is probably caused by the action of enzymes; and regeneration, or regrowth, is accomplished by the distribution of the chemical substance which composes chromatin.

The transition from the Protozoa to the Metazoa was effected during an age concerning which the rocks have little to tell us, for the life impressions left in the pre-Cambrian rocks have largely been destroyed by the terrific action of heat and pressure; but even this age has left us indirect evidence of the activity of living things, for the limestone accumulations point to algæ, and the iron and graphite deposits give evidence of iron-forming bacteria and chlorophyllic plants.

It is to pre-Cambrian time, then, an era of some forty million years, that we assign the evolution of the Metazoa from the Protozoa; for when we reach Middle Cambrian time we find ample evidence of highly specialized and widely distributed invertebrate (backboneless) life. This page of evolutionary history shows an increasing complexity in the actions and reactions of vital processes, as the single-celled organisms evolved into the many-celled organisms, or Metazoa—a division which now embraces all ani-

mals, except the Protozoa, from the lowest to the highest, including man himself.

Let us consider precisely what the change from Protozoa to Metazoa meant. It meant a distribution and a specialization of labor; work that had been done, in the most primitive animals, by a single cell, was to be done, in the higher animals, by a group of co-operating cells, dependent upon one another for existence. At first the many-celled organism might accomplish nothing more complex than was accomplished by the single-celled organism, but the distribution and specialization of labor gradually made possible increasing complexity of function. The animal became gradually more highly organized, more efficient in the struggle for existence, as the individual cells developed efficiency in their tasks and even undertook new tasks. Professor Osborn describes the beginning of this increase in complexity and efficiency when he writes:

"By Middle Cambrian time the adaptive radiation of the Invertebrata to all the conditions of life—in continental waters, along the shore-lines, and in the littoral and pelagic environment of the seas—appears to have been governed by mechanical and chemical principles fundamentally similar to those observed among the Protozoa, but distributed through myriads of cells and highly complicated tissues and organs,

instead of being differentiated within a single cell as in the ciliatea-like creative Protozoa. Among the elaborate functions thus evolved, showing a more complicated system of action, reaction, and interaction with the environment and within the organism, were, first, a more efficient locomotion in the quest of food, in the capture of food, and in the escape from enemies, giving rise in some cases to skeletal structures of various types; second, the evolution of offensive and defensive weapons and armature; third, various chemical modes of offense and defense; fourth, protection and concealment by methods of burrowing.

"There are heavy protective coverings for slowly moving and sessile (sedentary) animals. In contrast we find swiftly moving types with the lines of modern submarines, whose mechanical means of propulsion resemble those of the most primitive darting fishes. Other types, such as the Crustacea, have skeletal parts for the triple purposes of defense, offense, and locomotion, some being adapted to less swift motion. In Palæozoic time they include the slowly moving, bottom-living, armored types of trilobites, so named because their bodies consist of three lobes or segments. Among living species the horseshoe crab is nearest to the trilobites. Then there are other slowly moving, bottom-living forms, such as the brachiopods

and gastropods, with very dense armature of phosphate and carbonate of lime. (Brachiopods are a class of bivalve molluscs, distinguished by two fleshy, prehensile arms that can be thrust out or withdrawn; gastropods are a class, including snails and slugs, distinguished by the possession of a distinct head and a muscular, disk-like foot used for locomotion.) Finally there are pelagic, or surface-floating types, such as the jellyfishes, which are chemically protected by the poisonous secretions of their 'sting-cells.' "

So we see that the struggle for existence had already begun to result in the efficient specialization of the cells composing the multi-celled animal: digestive cells, fighting cells, muscle cells, and nerve cells—to name only a few—were developing. Thirty million years ago life on our planet was already assuming an amazing variety and complexity.

This was the age of the trilobites, equipped with that thick armor which has insured their preservation in exceptionally fine fossil form; this was the age of the sedentary, armored brachiopods, which have remained almost unchanged in form since their appearance in the Cambrian seas, thereby exhibiting a noteworthy stability of type. Primitive shrimps, rock-clinging sea-cucumbers, burrowing sea-cucumbers, and primitive jellyfish abounded in the time of which we speak. There were worms that swam and

burrowed, there were types equipped with fin and tail that foreshadowed the coming of the fish, and there were the ancestors of the spider, the scorpion and the mite. In fact, the sum of recent investigations and discoveries has led us to the conclusion that the Cambrian seas and seashore swarmed with as many varied, divergent types as are now found among the aquatic Invertebrata, that the evolution of the backboneless animal reached its limits about thirty million years ago. The appearance of a backbone in animals marks another great stage in the history of life upon our planet, and it is with the earliest members of the great Vertebrate family that we have next to deal. But first we shall turn aside once again from the main course of our narrative in order to clarify the nature of the evolutionary processes with which we are concerned.

The crux of Evolution, we may say, is the transformation of one plant or animal form or function into another. But how is this transformation effected? Where lies the source of the change? Is it accomplished suddenly, or gradually; is it the result of chance, or is it directed by some law? These, certainly, are questions of prime importance to the evolutionist, and we are now able to answer them with considerable certainty.

As regards the source of the causes responsible for new forms and functions, there are two historic explanations, both the work of great scientists, and both claiming a multitude of devoted adherents. Named after their promulgators, the older theory is known as the Lamarckian, and the more recent theory as the Darwinian. Lamarck held that we must seek for the desired causes in the body cells, which are affected by one another and by the environment, and which in turn affect the Heredity-germ. All changes in form, according to this theory, are controlled by function, and are adaptive or purposeful. The Darwinian explanation, on the other hand, as set forward by Weismann and de Vries, is that all predispositions toward new forms and functions begin in the germ cells, that the germ cells cannot be affected by outside influences, and that their predispositions are of an experimental or chance nature. According to this theory "fortuitous variations" are constantly being tested, and adaptation consists in the selection of the fittest.

But neither of these explanations is wholly satisfactory in view of all that we now know of palæontology and zoology. We are now forced to adopt a broader view of the subject, and we no longer seek our explanation in a single factor, but rather in the action, reaction and interaction of those four factors,

or energy complexes, which we mentioned in our first chapter: the physical, or inorganic environment; the developing organism; the heredity chromatin; and the living environment. It is in the study of these complexes that the hope of evolutionists now chiefly lies. For example, Professor Osborn writes:

"While it is possible that the relations of these four energy complexes will never be fathomed, it is certain that our search for causes must proceed along the line of determining which actions, reactions, and interactions invariably precede and which invariably follow those of the body cells (Lamarckian view) or those of the chromatin (Darwin-Weismann view). The Lamarckian view that adaptation in the body cells *invariably* precedes similar adaptive reaction in the chromatin is not supported either by experiment or by observation; such precedence, while occasional and even frequent, is by no means invariable. The Darwinian view, namely, that chromatin evolution is a matter of chance and displays itself in a variety of directions, is contradicted by palæontological evidence both in the Invertebrata and Vertebrata, among which we observe that *continuity and law in chromatin evolution prevail over the evidence either of fortuity or of sudden leaps or mutations*, that *in the genesis of many characters there is a slow and prolonged rectigradation or direct evolution of the chromatin toward*

adaptive ends. This is what we meant in our introduction by the statement that in Evolution law prevails over chance."

We have yet to answer the question of how one plant or animal form passes into another. And is it accomplished suddenly or gradually? Hugo de Vries has given us the answer for the plant world; Wilhelm Henry Waagen the answer for the animal world. The first has shown that plants are capable of frequent sudden changes, or mutations; the second has demonstrated that animal evolution works through a series of continuous, minute, and cumulative changes. This difference is easily understandable, for while plants are much more limited in their evolution than animals, they are much more powerfully affected by changes of environment. Such a change means a great difference in the source of plant energy, while it involves only a slight difference in the source of animal energy.

So we see that evolutionary study, to-day, is directed along two principal lines: the evolution of the visible body, and the evolution of the invisible germ. The one is studied by observation of form and function; while the other can only be *inferred* from the visible evolution of form and function, as the Heredity-germ cannot be directly studied in its life processes, because of its microscopic size, because of the

extreme slowness with which changes occur in it, and because it dies at once upon removal from the living body. Investigation along these two lines shows us that we are dealing with two clearly differentiated subjects: on the one hand, the body cells are unstable and subject to the immediate action of environment: while, on the other hand, the chromatin, or the germ, is stable and very slow to manifest alterations. The relation between these two factors has been suggested in the preceding paragraphs, and it is toward a more perfect understanding of that relationship that evolutionists are continually working.

It is worthy of note that while Darwin was constantly searching for the causes of the *origin of species*, contemporary evolutionists are studying the origin and evolution of single "characters," (*i. e.*, brown or blue eyes, long or short fingers, etc.) for it is obvious that a new species simply represents a noticeable accumulation of new or modified characters. This study shows us that all the characters in an individual do not develop at the same speed: some are retarded, others are stable, others accelerated; and this question of *character velocity*, as it is called, is now considered of prime importance.

The unscientific reader has probably heard much of *adaptation* in connection with evolution, and by this is meant changes in form and function which are

calculated to fit the organism to its environment, to make it more efficient in its struggle for existence. Thus *adaptive* changes affect the organism's efficiency in the capture of energy, in moving, fighting, running away, and reproducing itself. We find that when animals radiate widely in their quest for food they exhibit a wide divergence of forms, while when they draw together there is manifested a constantly increasing resemblance of structure. This law of *adaptive radiation* has been stated by Osborn, who has supplemented Waagen's work in demonstrating the adaptive nature of the slow, cumulative changes in animal form traced by that scientist.

To make clear the consequences of this adaptation, let us quote one more passage from Professor Osborn, which points out the disadvantages of continuous residence in one life environment.

"Through the *law of compensation*, discovered by Geoffroy St. Hilaire early in the last century, every vertebrate in developing and specializing certain organs sacrifices others; for example, the lateral digits of the foot of the horse are sacrificed for the evolution of the central digit as the animal evolves from tridactylism to monodactylism (from three-toedness to single-toedness). These sacrificed parts are never regained; the horse can never regain the tridactyl condition, although it may re-enter a habitat zone in

which three digits on each foot would serve the purposes of locomotion better than one. In this sense chromatin evolution is irreversible. The extinction of vertebrate races has generally been due to the fact that the various types have sacrificed too many characters in their structural and functional reactions to a particular life habitat zone. A finely specialized form representing a perfect mechanism in itself which closely interlocks with its physical and living environment reaches a cul-de-sac of structure from which there is no possible emergence by adaptation to a different physical environment or habitat zone. It is these two principles of too close adjustment to a single environment and of the non-revival of characters once lost by the Heredity-germ which underlie the law that the highly specialized and most perfectly adapted types become extinct, while primitive, conservative, and relatively unspecialized types invariably become the centres of new adaptive radiations."

Now, with an appreciation of the relationship that binds together body cells and heredity cells, and with some understanding of the adaptive laws which govern the evolution of forms, let us proceed to consider the first members of the great family of Vertebrates.

CHAPTER V

FISHES AND AMPHIBIANS

THE appearance of an animal backbone upon our planet may be regarded as one of the most important events in living history. Precisely when this structural feature made its début, and what creature was its possessor, we shall not presume to say; but the earliest backboned creatures of which we have knowledge were fishes, whose fossils have been partially preserved for us, and the period to which they belonged was the Ordovician, the age immediately following the Cambrian, in the early Palæozoic epoch (see Chart A, page 16).

But we have good reason to believe that these fishes were the product of even earlier vertebrate (backboned) evolution, for they were slow-moving armored types, and we know that such types are invariably preceded by defenseless types which depend upon speed for success in the struggle of life. So we assume that our first vertebrates were swift-swimming, darting fishes of a type that may be more or less accurately represented by the existing lancelet.

From this main, primitive group, we assume that

there diverged or radiated a number of other groups: the slow-moving, narrow-bodied fishes which inhabit the middle-depths of the sea; the bottom-dwelling types, which are flattened out laterally, and which often develop an increasingly thick protective covering; and the elongated, swift-moving types which develop into the eel-type that is devoid of ventral fins. We note that fish evolution illustrates the law, applying to all vertebrates including man, that development of protective covering is compensated for by loss of speed, whereas increase in speed involves decrease in armament. We note also that these fish types exhibit an increase in size and increase in specialization which attains its maximum just before the extinction of a type.

Regarding the early armored fishes of the Ordovician period we know very little, aside from the fact that their bodies were encased in rigid plates or scales. Tracing the central line of fish development, we may divide the whole fish class into three sub-classes or groups, differentiated by their physical characteristics and by the times of their appearance on the Earth. The first and oldest group, which appeared in the Upper Silurian and Devonian periods, is represented to-day by such fishes as the sharks and rays, which have no real bones but merely ribs of cartilage (elastic tissue from which bone is formed). This first

group is sub-divided into two main types: the torpedo-shaped forms which appeared in Silurian time; and the large-headed, bottom-dwelling type which developed in the Devonian epoch. At the same time that this bottom-dwelling type was developing the primitive shark group was radiating into the elongated, sinuous type of the frilled shark.

The second group with which we are concerned belongs to the Upper Devonian period, and the fishes that it includes are known as Ganoids; the sub-class now being represented by the sturgeon, the bony pike and similar scaled fishes.

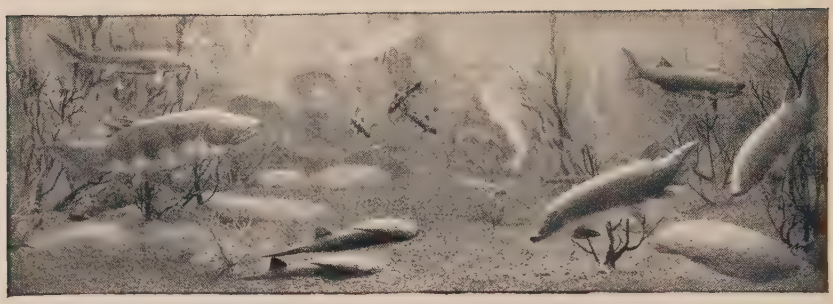
The Ganoids, in turn, gave rise to the Teleosts, which made their début in the Jurassic age and which include in their number all true bony fishes. It is to this group that the great majority of living fishes belong; the primitive armored types, for example, having become virtually extinct in Upper Devonian time. Remotely allied to the second group are the first "lung-fishes" and the "fringe-finned" Ganoids—which bring us to the question of how the first land animals evolved.

Before considering this question, the reader should fix firmly in his mind the amazing fact that the larger portion of the whole history of life upon our planet is the history of aquatic organisms. For millions and millions of years there was not a single animal that

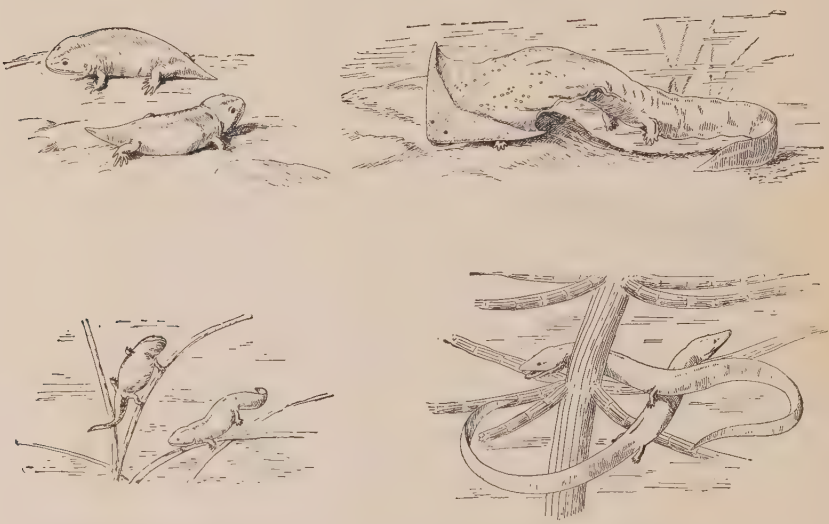
C

D

1, restoration of giant eurypterid (*Stylonurus excelsior*) from the Catskill sandstone. Natural length, four feet. *B*, restoration of *Eusarcus* from the Bertic water lime. Natural length, three feet. *C*, *D*, fossil Cambrian Trilobites; Neolenus (*C*), Burgessia (*D*) Fossil Shrimps.



Restoration of typical fossil fishes of Devonian time. *After Bashford Dean, American Museum.*



Restoration of typical fossil amphibians of carboniferous and Permian age. *After Gregory and Osborn, American Museum.*

made its home upon the land. It was not until Devonian, or at the earliest Upper Silurian, time that the great passage of life from sea to shore began. And the true land types were developed only after a long period of intermediate amphibian evolution, during which certain organisms clung to a watery life as long as possible while gradually adapting themselves to the conditions of terrestrial existence. We may assume that the passage from one environment to another was motivated, as all such migrations are, by the need of food; struggle for life in the waters along the coast was becoming increasingly difficult and more fiercely competitive; the low-lying, semi-tropical Earth, with its growths of towering ferns and dense mosses, offered a rich store of food to the animals that could adapt themselves to a life ashore. Slowly the passage was accomplished, first from the coastal waters to muddy flats, then from the muddy flats to *terra firma*. What creatures effected this remarkable and eventful migration? How did they adapt themselves to the changed environment? These are questions of prime importance, and they have provoked many a scientific conflict.

In the rivers of Australia there are, to-day, certain fishes which are equipped with a lung as well as with gills, and in some rivers of South America and Egypt there are similar fishes possessing two lungs. The

importance of these lungs is realized when we learn that the single-lunged fishes inhabit rivers that partially dry up during the summer-time, while the double-lunged fishes inhabit rivers that dry up entirely. During the rainy season these well-equipped creatures swim about and breathe water through their gills like any ordinary fishes; but once the dry season arrives they promptly take refuge in the mud of the river-bed and breathe in air through their lungs like any of the higher vertebrates. Here then are true amphibians, creatures equipped both for air and water breathing; and scientists long assumed that the ancestor of these fishes, the primitive lung-fish, furnished the connecting link between the true fishes and the air-and-water-breathing amphibians of the Devonian age. Upon the basis of embryology and comparative anatomy no theory could seem surer. From fossil remains we know that the lung-fishes, or *Dipnoi*, were at one time distributed throughout the inland rivers of the entire earth, and it was long held that the first move from the water to the land was made by some branch of this family which was physically equipped to breathe air as well as water. Carl Gegenbauer, the eminent German anatomist, for example, piled up anatomical evidence in favor of this engaging theory, and he attracted many enthusiastic followers. Indeed, in most popular works on

Evolution, the lung-fishes are still presented as the connecting link between aquatic and terrestrial existence.

But palæontology has furnished evidence that upsets the conclusions of embryology and comparative anatomy; and the discovery of the most primitive types of the fringe-finned Ganoids has led us to the true ancestors of the first amphibians. We know now that credit for the great migration is due to those fishes with a central fin of cartilaginous rods, and that as they moved from the water to the mud flats, and thence to the dry land, their fin, which had been used for propulsion through the water, was gradually transformed into a propelling limb. So the line of descent, as we now trace it, runs as follows: the first amphibians evolved from ancestral Silurian ganoids through the fringe-finned ganoids; from the first amphibians sprang the ancestors of the reptiles and the amphibians of the salamander type; and from them, too, evolved the solid-skulled amphibians of Permian and Triassic time, from which our toads and frogs are descended.

Regarding the transitional period with which we are dealing, Professor Osborn writes: "A single impression of a three-toed footprint (*Thinopus antiquus*) in the Upper Devonian shales of Pennsylvania constitutes at present the sole palæontologic proof of the

long period of transition of the vertebrates from the fish type to the amphibian type. This transition was a matter of thousands of years. It took place in Lower Devonian if not in Upper Silurian time. Under the influence of the heredity-chromatin it is now rehearsed or recapitulated in a few days in the metamorphosis from the tadpole to the frog."

If the reader will look at a living newt or at a salamander he will see the nearest existing representative of the primitive amphibian type. These creatures were, for the most part, long of body, small of head, short of limb, and dependent upon their tails for propulsion. But from this primordial type other types began to radiate in response to the various environmental conditions in which they found themselves as a result of their quest for food. It is probable that this radiation began in Middle Devonian time and continued through the coal-forming Carboniferous age.

When we reach Upper Carboniferous and Permian time in South Africa, just before the first Glacial Period, we encounter tremendous geologic changes, involving the elevation of the land and the recession of the sea, which were peculiarly favorable to the evolution of the land-dwelling amphibians. So they radiated widely, reproducing many of the forms that had been evolved by the fishes and anticipating many

of the chief forms which were to characterize the evolution of the reptiles. One atavistic characteristic was the retention of a scaly coat in certain types, which recall the early ancestors from which these creatures sprang; but these scales gradually dropped away, and with them the ability to form a bony, armored covering.

We have a rich and abundant variety of fossils from which to study these amphibians of the Carboniferous forests. There were no birds in these forests, but there were many crawling creatures of the beetle and spider kinds, and there were winged insects—the first creatures to take the air. There ranged through these swampy forests enormous precursors of our small newts and salamanders; and there were creatures that, having ceased to use their propelling limbs, foreshadowed the development of the reptiles. We may assume that these sinuous, snake-like forms were first developed through the necessity of wriggling through dense undergrowth in search of food, or in an effort to escape. As the body became more and more supple, more and more adept at this wriggling process of locomotion, the limbs ceased to be useful, and, once the period of their utility was past, they began gradually to disappear. Other types of amphibia developed tree-climbing abilities in their quest for insect food, and this in turn gave rise to

fresh forms in the insect world; for as we trace the struggle for life down through the ages, we note that any adaptations among the hunters produce, by reaction, adaptations among the hunted. To put the matter crudely, if one type of amphibia becomes capable of climbing a tree in order to capture insects, those insects are likely to develop wings with which to make their escape; and this is precisely one of the developments which occurred in the Carboniferous age. Other insects found other means of survival, such as the development of protective coloration, for example.

So we see that there was an abundance of living creatures in those far-off Carboniferous forests, and that these creatures variously affected one another's development in the intense struggle for existence that they waged unceasingly amongst themselves. The great transformation that they all underwent in common was the result of their common struggle with a new environment—the land; and this transformation was effected in the organs of respiration and blood circulation. At first the lung or lungs was an organ for only occasional use, when the lowest amphibia came to the surface or crept ashore for a brief period; but gradually, as they spent more and more time upon the land, the lungs displaced the gills and the latter finally disappeared. Simultaneously,

the single heart chamber is divided into two auricles by the growth of a partition, and the circulation of the blood is consequently changed. But the reader must realize that all these changes—both those shared by all the amphibia and those of the individual forms—required an enormous period of time for their accomplishment. They were a slow response to the changes in general and individual environment. The period with which we are dealing was one in which vast tracts of land were gradually being drained dry by the tilting and rise of the continents, and the drawing back of the sea. The amphibians represent an organic response to the early stages of these geologic upheavals: the first amphibian types with which we are familiar were equipped with dual systems of respiration and locomotion, with lungs and gills, with limbs and a propelling fin. But as the land area increases in extent, certain amphibians gradually lose their dual character, and purely terrestrial animals make their appearance. In these types gills disappear forever, and the propelling fin is rendered useless by the development of legs and feet: the long-tailed salamander, having enjoyed its brief day as the highest product of creation, gives way to the short-tailed reptile, and we are at the dawn of a new age.

The amphibians reached the climax of their devel-

opment in Permian time; the reptiles made their first appearance just before the great Permian Ice Age which was to cause such a revolution in terrestrial life. This was the first glacial period that matters in our history of Evolution, for the two preceding ones occurred when there was no life upon the land. Enormous changes in the organic world were effected by this glaciation, which covered approximately four million square miles of our Earth's surface with a sheet of snow and ice. It was the southern hemisphere which was immediately affected; the ice-sheet spread over what are now Australia, India, and southern Africa. There is geologic evidence that an arid condition prevailed in the northern hemisphere throughout the greater part of the Permian age—evidence furnished by the reddish color of the rocks of Europe and the southwestern United States in which fossil remains of the solid-headed amphibia and the earliest reptiles are found. But there were small local ice-sheets, scattered here and there over the northern portions of the globe, and all the living creatures on our Earth were forced at this time to cope with a more or less marked climatic change. Having reached the eve of this change, we have now to consider the origins of the reptiles, and later of the birds.

CHAPTER VI

REPTILES

IT is comparatively recently that naturalists have agreed upon a definitive separation of the amphibians and the reptiles, and the similarities of the earliest representatives of both classes still give rise to considerable difficulties in classification. The most primitive solid-headed reptilian type and the solid-headed amphibian type are, for example, very much alike; and if we study them bone by bone we clearly perceive that both are descended from the skull type of the fringe-finned fishes, of which we have spoken earlier.

This similarity of amphibiáns and reptiles is easily understandable when we take into consideration the fact that both groups were adapting themselves to the environment conditions of the Permian (see Chart A, page 16) continents at about the same time, with the natural result that they closely paralleled each other in many of their external features. But careful study shows that the true reptile is primarily a land animal, rather than a land-and-water animal, that its sensory organs and nervous reactions are more highly devel-

oped than those of the amphibians, and that its cold-blooded circulatory system is more highly perfected. In the extent of their radiation and mechanical adaptation the reptiles far surpassed the amphibians, and equalled the mammals which were to follow them. This period of radiation occupied from fifteen to twenty million years, and the ancestral environment was a semi-arid, warm region which favored brisk motions, scales, slender limbs, a supple tail, and sharply pointed teeth and five-clawed hands and feet for the capture of food.

Tracing the adaptive radiation of the reptiles, we find first, as in the case of the fishes, the swiftly moving, torpedo-shaped or fusiform type. The monitor lizard is the living representative of certain members of this group; while others of the group were quadrupeds, with well-developed feet and limbs, that used their long tails for the purposes of equilibrium. In the primitive, lizard-like *Varanops* (belonging to the order of the *Pelycosauria*) we find a creature that may well have been the ancestor of all the eighteen orders of reptilia with which we are familiar; for, so far as structural evidence goes, the lizards, the alligators, and the dinosaurs might all be descended from it. But as yet we are not sure whether the various orders of reptiles are descended from a single, a double, or a multiple stock. The primitive reptiles of this first

class inhabited the seashore and the lowlands and fed either upon insects or smaller animals.

Turning to a more amphibian-like group we encounter reptiles equipped for an aquatic existence, such as the *Limnoscelis*, which with its short, crocodile-like head, is equipped with paddle-feet, and can propel itself through the water by means of its long tail. We note, incidentally, that as the reptiles adapt themselves to a purely land existence, the tails are sometimes reduced in length, while the limbs are strengthened and the protective armor perfected. In certain types this armature takes the form of a bony or scaly integument, while in other types the skull alone is protected by hard little knobs or bosses. Among the most remarkable specimens of early reptilian life are the giant, fin-backed lizards which are found in the Permian deposits of Texas and which were probably land-living and flesh-eating in their habits. The striking feature of these creatures is that a number of spines project straight up from their backbone for the purpose of supporting a powerful fin resembling that of the sail-fish which is found off the Florida coast. This membranous fin gives the animal a truly weird appearance.

But when we compare the Permian deposits of South Africa with those of the American continent, we discover that the former present a much more

extensive adaptive radiation of reptilia than do the latter; a fact which we may attribute to the greater geologic stability of Africa when compared with the other continents. In the shales and sandstones of South Africa we find no less than 115 distinct species of Lower and Middle Permian reptiles represented. These include enormous, grass-eating reptiles with rounded bodies, huge limbs, and rounded heads, resembling the lizard-like reptiles found in the Permian deposits of Texas. Their eyes were large and their limbs enabled them to move swiftly. Then there were reptiles that anticipated the mammals in their skull development; and slim-legged reptiles that seized upon their prey with sharp dog-like teeth. Among the rest moved the massive creatures that we have named the "terrible-headed," with their high, arched backs, bulging foreheads and wide jaws; while still larger were the *anomodonts* (or "lawless-toothed") whose skulls were sometimes nearly a yard in length, and whose cruel jaws terminated in a horned beak.

Considering *en masse* all the reptiles of the Lower and Middle Permian age, we find that they form a nearly complete social group. Here are animals of all sizes, of widely differing structure, and of markedly various habits; here are plant-eaters, flesh-eaters, and eaters of both flesh and plants; here are creatures equipped with sharp, predatory teeth, and here are

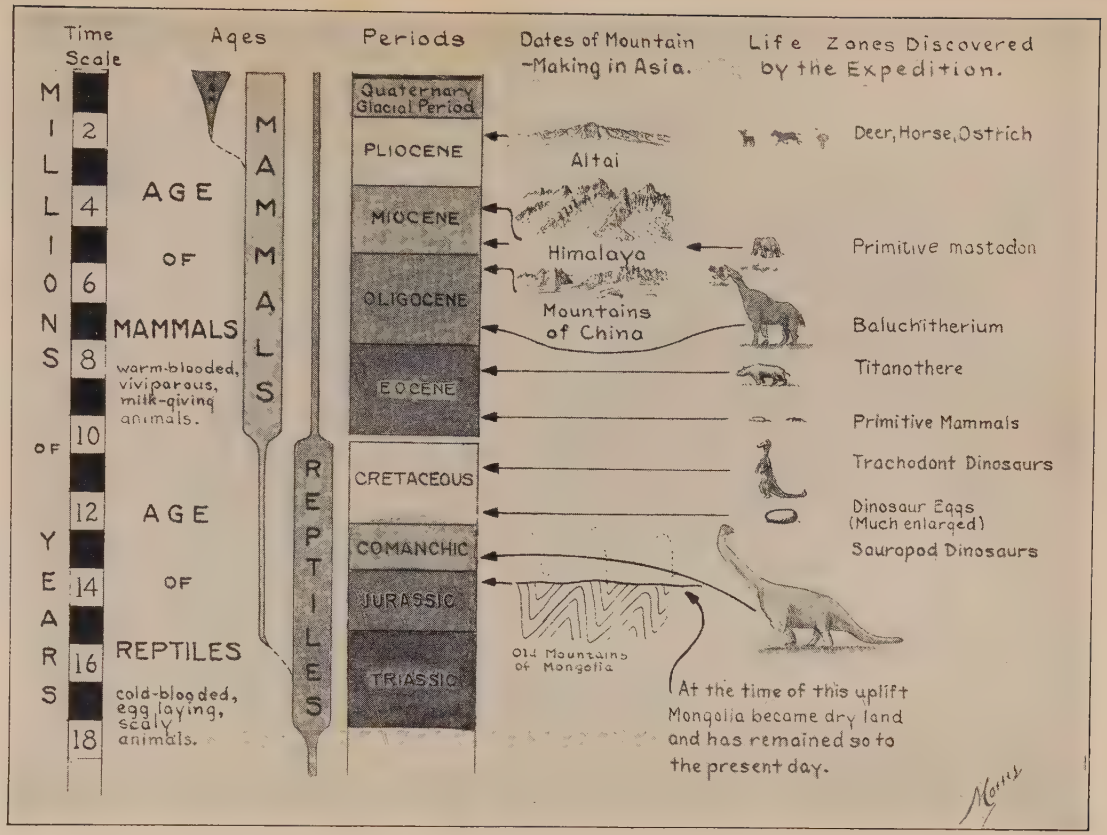
toothless monsters with horned beaks; here are the swift and the slow, the wholly unarmored and the partially armored. One type alone is lacking to make the group complete: the sluggish, completely armored type.

These many reptiles present a living society that is bewildering in its complexity, but there is one type that the thoughtful student will seek to single out from amongst them all: the type or types from which the mammals were to arise. And he will not seek in vain. Purely anatomical evidence led Huxley to believe that the mammals probably arose directly from the amphibians, but palæontology has shed new light upon the subject, and we can now trace our remote ancestors back to certain pro-mammalian, reptilian types. These are the *cynodonts* (or dog-toothed) and the *theriodonts* (the mammal-toothed).

Considering these types we are led to wonder what natural causes fitted them to become the ancestors of the higher class of mammals, and we can do no better than to quote Professor Osborn's answer to this question, for he has phrased it in the simplest, most conclusive manner.

In "The Origin and Evolution of Life," he writes: "At least two reasons are apparent. First, these larger and smaller types of South African pro-mammals exhibit an exceptional evolution of the four

limbs, enabling them to travel with relative rapidity, which is connected with ability to migrate, powers doubtless associated with increasing intelligence. Another marked characteristic which favors development of intelligence is the adaptability of their teeth to different kinds of food, insectivorous, carnivorous, and herbivorous, which leads to development and diversity of the powers of observation and choice. In this adaptability they in a limited degree anticipate the evolution of the mammals, for the other reptiles generally are distinguished by a singular arrest or inertia in tooth development. Rapid specialization of the teeth is one of the chief features in the history of the mammals, which display a continuous momentum and advance in tooth structure, associated with specialization of the organs of taste. Of greater importance in its influence on the brain evolution of the early pro-mammalian forms is the internal temperature change, whereby a cold-blooded, scaly reptile is transformed into a warm-blooded mammal through a change which produced the four-chambered heart and complete separation of the arterial and venous circulation. This change may have been initiated in some of the cynodonts. This new constant and higher temperature favors the nervous evolution of the mammals but has no influence whatsoever upon the mechanical evolution. As pure mechanisms the cold-



Chronological divisions of the Age of Reptiles and of the Age of Mammals as observed in eastern Asia.

Restoration of the giant amphibious dinosaur known as *Apatosaurus* or *Brontosaurus*. *After Osborn and Knight, American Museum.*

Restoration of the giant carnivorous dinosaur, *Tyrannosaurus rex*, approaching a group of the herbivorous dinosaurs, *Triceratops*, fossil reptiles typical of upper Cretaceous time. *After Osborn and Knight, American Museum.*

blooded reptiles exhibit as great plasticity, as great diversity, and perhaps higher stages of perfection than the mammals. Nor does increasing intelligence, as we shall see, favor mechanical perfection."

There are philosophical implications in these two last sentences upon which we have no time to dwell; but even as we pass on it is worth noting that the development of a constant blood temperature and the increase of intelligence gave rise to qualities and abilities that could no longer be judged by purely mechanical standards. The reptile may represent a perfected mechanical development; the higher mammals are to represent a development that has passed beyond the realm of mechanical measurements.

Taking a bird's-eye view of reptilian evolution, we find that the primitive reptiles made their appearance in Upper Carboniferous time, and radiated into eighteen orders, three of which achieved their full evolution in Permian and Triassic time and then became extinct. In Permian time the ten early adaptive branches of the reptilian stem were already flourishing and ready to give forth the numerous representatives of Mesozoic reptilian age. Of the eighteen reptilian branches, only five were to outlive the Age of Reptiles and survive into Tertiary time. Eight branches perished in Permian and Triassic time in consequence of premature and

excessive specialization; and five other branches, which dominated the planet during the late Mesozoic era, became extinct at the close of that era. The five branches which persisted are represented to-day by the turtles, the tuateras of New Zealand, the lizards, the snakes, and the crocodiles. These are the humble survivors of the reptilian dynasties which lorded it over our planet for a period of eighteen million years, before the rise of the mighty mammals.

Among the reptiles were developed numerous types whose size was truly amazing when compared with that of any creatures now treading the earth. One of the Sauropods reptiles, which reached the peak of their development at the close of Jurassic time, was a gigantic type named *Brachiosaurus*, at least a hundred feet in length. Then there was the *Brontosaurus* ("thunder-saurian"), a heavy-limbed, bulky creature that inhabited the flooded plains and lagoons of our far West, which weighed some forty thousand pounds, when fully grown, and measured about sixty feet. Some twenty feet longer was the *Diplodocus*, comparatively light of body and swift of movement, with a tail of enormous length. Then there were leaping reptiles, with powerfully developed, slender limbs, ranging in height from two to forty feet. And most rapacious of all was the *Tyrannosaurus rex* (Osborn), "king of the tyrant saurians," with huge hind limbs

and dwarfed fore limbs, described by Professor Osborn as "the most destructive life engine which has ever evolved." This fantastic work of nature possessed a brain weighing less than one pound, or less than one four-thousandth of its total weight, and was a perfect example of mechanical perfection almost wholly devoid of higher intelligence.

But we must turn away from these remarkable individual specimens to trace briefly the more general lines of development which marked the evolution of the reptilian age. In late Permian or early Triassic time a branch known as the Dinosaurs sprang from the small, four-footed, lizard-like group, and this branch was destined to dominate all other land-dwelling reptiles until its extinction at the close of the Cretaceous age. This class, which was unsurpassed among the Reptilia for variety of types and notable individual specimens, falls into two subdivisions: the flesh-eaters and the plant-eaters. As we have seen, the mighty *Brachiosaurus* was the most notable member of the latter class; while the former class reached its supreme development in *Tyrannosaurus rex* (Osborn).

A great number of the earliest *dinosaurs*, and especially the flesh-eaters, were bird-footed and capable of a swift-running movement, their rounded bodies being lifted completely clear of the ground and being

balanced by a long tail. One of the later types, which made its appearance in the Upper Cretaceous age, was the *Struthiomimus*, "ostrich dinosaur," which was bird-like not only in the formation of its feet and limbs but also in its toothless jaw which assumed the form of a horned beak. This creature, distinguished by its speed, marks the transition from the flesh-eating to the plant-eating types.

When the plant-eaters developed as an offshoot from the primitive flesh-eaters, they gradually underwent a reversed evolution from a swift-moving two-legged type into a slow-moving four-legged type; for they no longer required speed of movement in the capture of food. But they paid the penalty for this loss of speed, as it made them the prey of the flesh-eaters; and one of the most dramatic reconstructions of Upper Jurassic life is the picture of a carnivorous dinosaur feeding upon the carcass of a giant Sauropod.

The Sauropods inhabited the swamps and flooded plains of the world as it existed in their day, achieving a world-wide distribution, and reaching the climax of their evolution in late Jurassic and early Cretaceous time. In North America they became extinct in Lower Cretaceous time, but there is evidence to show that they persisted in Southern France and in Patagonia until the close of the Cretaceous period. Explaining their disappearance from the earth, Pro-

fessor Osborn remarks: "In the final extinction of the herbivorous sauropod type we find an example of the selection *law of elimination*, attributable to the fact that these types had reached a cul-de-sac of mechanical evolution from which they could not adaptively emerge when they encountered in all parts of the world the new environmental conditions of advancing Cretaceous time."

But there were other herbivorous dinosaurs besides the sauropods, and among these were the Iguanodonts, which retained the two-legged form and depended wholly upon speed for escape from their enemies. Ceasing to feed upon flesh, these creatures lost their front teeth and developed a bird-like beak, or horny sheath, suitable to their plant-eating habits. They are known as "duck-bill" dinosaurs, and they managed so well in the struggle for existence that they spread all over the Northern hemisphere, radiating into three distinguishable groups, all of which survived without the aid of any armor.

Still another group, known as stegosaurs, developed a partial armament composed of plates and spiny defenses, simultaneously reverting to a four-legged, comparatively sluggish locomotion. These creatures when attacked tucked their head and limbs beneath their armament, much as the porcupine does to-day, and sought to ward off their foes by rapidly

swinging their spiny tails back and forth. They became extinct during the Cretaceous period, but not before they had given rise to two other grass-eating types. One of these (the *Ceratopsia*) developed frontal horns and a kind of bony gorget for the neck, as an answer to the increasing offensive powers of their enemies, the flesh-eating dinosaurs.* So we find that the Ceratopsia achieved the most perfect defensive development at precisely the time that the flesh-eaters found supreme expression in the ferocious *Tyrannosaurus rex*. But another type of grass-eater (the *Ankylosaurus*) was to develop the most complete defense against the predatory carnivora. This creature was entirely sheathed in a coat of thick, bony armor; unnecessary teeth were replaced by the familiar horned beak; and the animal, thus thoroughly protected, became more and more sluggish in its movements. We can gain a general idea of this creature by looking at our modern armadillo.

In following the development of the terrestrial reptiles we have so far neglected the parallel evolution of the aquatic forms, and we must now turn to them before dealing with the origin of birds.

*The famous dinosaur eggs belong to one of the earliest and most primitive of the Ceratopsia, called *Protoceratops*, which—unlike the later characteristic forms—had no horns. Fossil remains of *Protoceratops*, showing all the stages of growth from egg to adult, were brought back from the Gobi Desert of Mongolia and are now exhibited at the American Museum of Natural History, New York.

In an earlier chapter we described a migration of living forms from the water to the land; here we are concerned with a reversal of this journey, for during Permian, Triassic, and Jurassic time, when certain branches of the reptiles were perfecting the organs required for life upon land, other branches were turning backward to an aquatic existence. Indeed, no less than eleven of the eighteen reptilian orders participated in this *reversed adaptation* which involved various transitional stages; and no less than six orders finally reached a deep-sea existence. Such creatures as the ichthyosaurs and plesiosaurs, the crocodiles and snakes played the rôles in ocean life that are played to-day by the dolphins, whales, and porpoises—the turtles being the only high-sea reptilian survivors from this period.

Even more remarkable than the examples of reversed adaptation are those of *alternate adaptation*, as demonstrated, for instance, by the leatherback sea-turtle. We have reason to believe that this creature first passed through a long period of evolution upon land, acquiring a bony armor for the purposes of defense, and that it then entered an aquatic life, during which it lost all of this armament. But, returning once more to a terrestrial existence, it developed an entirely new armament, quite different in design from the first. This, however, was not the end, for de-

scendants of the second type returned to the sea, losing this second coat of armor and developing in its place a leathery covering, thus reaching the stage of the existing *Sphargis*.

Perhaps the best example of simple reversed adaptation is furnished by the ichthyosaurs, which developed superficial fish-like characteristics while retaining an internal anatomy typical of land-living animals. With the ichthyosaur we may trace back a line of evolution that we have already followed; in this case passing from a comparatively slow, four-footed, terrestrial form into a swiftly moving, torpedo-shaped, fish body. The plesiosaurs and the mosasaurs were among the types that accompanied the ichthyosaurs in their return to the sea. This phase of aquatic reptilian life found favorable conditions in the Jurassic continental seas; but the sea reptiles attained their highest evolution and widest distribution in Upper Cretaceous time when large portions of Europe and North America were submerged.

As we come to the close of this chapter on the reptiles and approach the Age of Mammals, we must note a remarkable fact. We have seen that only five reptilian orders have survived to our day, namely, the Testudinata, Rhyncocephalia, Lacertilia, Ophidia, and *Crocodilia* (*turtles* and *tortoises*, tuateras, *lizards*, *snakes*, and the crocodiles and *alligators*), and

the astonishing fact is that these five orders have made practically no evolutionary progress during the three million and more years that separate us from the Age of Reptiles. As Professor Osborn has stated the case: "During this period of three million years the entire plant world, the invertebrate world, the fish, the amphibian, and the reptilian worlds have all remained as relatively balanced, static, unchanged, or persistent types, while the mammals, radiating three million years ago from very small and inconspicuous forms, have undergone a phenomenal evolution, spreading into every geographic region formerly occupied by the Reptilia, and passing through multitudinously varied phases not only of direct but of alternating and of reversed evolution. During the same epoch the warm-blooded birds were doubtless evolving, although there are relatively few fossil records of this bird evolution."

Scientists of the day before yesterday might have sought to explain this arrested reptilian evolution upon the grounds of environment or bodily inertia; but the scientist of to-day seeks the explanation in the internal Heredity-germ, and arrives at the conclusion that arrested evolution is simply evidence of a slowing down of such physicochemical interactions as we have described in an early chapter. When chemical messengers are active, Evolution is rapid;

when they are inactive, Evolution is checked. Holding the view that Evolution is the sum of the changes manifested in single characters, we must conclude that the reptiles reached a static state when the greater number of their individual characters lost their velocity. We shall pass on now to the great Age of Mammals, which culminates in the appearance of man himself.

CHAPTER VII

THE RISE OF THE BIRDS AND MAMMALS

IT is a little difficult to decide upon the best place at which to introduce the bird into this history, for the creatures of the air have left us few traces of their early evolution, and the origin of flight still remains a somewhat obscure problem. But it is, perhaps, fitting that we should grant the bird a small place in this first chapter on mammals, for birds and true mammals made their appearance simultaneously, in Jurassic time, when the great dinosaurs were lording it over the world of forests and of swamps. And we have some reason to believe that they were both products of the colder latitudes of the Northern hemisphere; for their warm blood, four-chambered hearts, feathers, and fur, and their extraordinary solicitude for their young, are obviously responses to a cold environment. In the comparative warmth of the late Mesozoic Age, these creatures who were so admirably equipped for a colder habitat must have seemed strangely out of place; and surely no brontosaur, had he possessed a thinking brain, could have dreamed that both birds and mammals were des-

tined to outlive him and his kind, and that the latter were to produce a species that would dominate the Earth as no other species had ever dominated it.

Who the first creature was who took to the air we

Primitive bird (*Archæopteryx*) with its grasping arms and long tail, compared with the living pigeon (right) with its flying arms and short tail. *After Heilman and Osborn.*

do not know; but we do know that even before feathered birds existed there were reptiles (called *pterosaurs*) with leathery wings, which were capable of a soaring flight. These creatures, however, are not now regarded as being in the true line of bird evolution; theirs was an independent development. For the ancestor of the first birds we turn back to a small reptile, resembling a lizard, which took to the trees for the sake of safety. This reptile developed claws that enabled it to cling and swing from limb to limb, and its first flights through the air were doubtless no more than a parachute passage from tree branches to the ground. A close examination of feathers and

scales will show you that they consist of the same material, and it is supposed that scales developed into feathers in accordance with the requirements of a short, gliding flight. Whether the first birds began by developing two wings or four wings is still a debated point; but it is agreed by all that bird evolution began with passage from a terrestrial to a pure arboreal life, and that a second terrestrial phase followed, during which a rapid, running movement over the ground was developed as a secondary characteristic. The arboreal birds also gave off, as a branch stock, the aquatic birds; among which there was a certain loon-like creature, *Hesperornis*, a bird of the West that swam the Upper Cretaceous seas of America at the same time as the pterosaur and the mosasaur. These birds were divers, and were, of course, first tempted to leave the shore-line because of their desire for food. Like all swimming birds, they exhibited an example of reversed adaptation—the wing gradually assuming the functions of a fin or a paddle, and the body tending toward the fusiform, or torpedo shape, which is so admirably adapted to movement through the water.

But we have granted the bird all the space to which it is entitled in our general scheme. The important facts to remember are that the birds made their appearance from the same causes as the mammals, that

their warm blood and higher organization were a defense against a cold environment, and that flight was undoubtedly one of the many activities evolved by the hunted in their eternal efforts to escape from the hunters.

What is it that distinguishes the mammals from all other classes of living creatures? The answer lies in the name itself, for *mamma* is the Latin word for breast or teat, and mammals are animals that possess nutritious glands for the young. More specifically, mammals are distinguished by the fact that their females possess glands in which they secrete milk for the nourishment of their young. The mammals include the most widely varied types, creatures that seem as far apart as the poles, and as Professor Osborn has remarked: "It required a man of genius like Linnæus to conceive the inclusion within the single class Mammalia of such diverse forms as the tiny insect-loving shrew, smaller than the mouse, and the gigantic predaceous sperm-whale, ninety feet in length."

The mammal, then, is primarily a creature that suckles its young; but the class is differentiated from other classes by other notable features. Like the birds, and unlike the reptiles, mammals have four-chambered hearts and warm blood. In other words,

their blood remains at a fairly even temperature despite the fluctuations of environmental temperature. In the case of the lowest members of the mammalian class, however, it must be noted that the blood temperature fluctuates considerably. Another characteristic of the mammal is its coat of hair or fur, which, it appears, did not evolve from the reptilian scales as did the feathers of the bird, but *probably* grew up beneath the scales, thereby rendering them unnecessary and causing them to slough off. In this connection it should be noted that one family of mammals, the Pangolins of India, has genuine scales, but in their case hair grows in the spaces between the scales and on the portions uncovered by them. Another feature of the mammals is that, no matter what modifications the fore limbs may have undergone, they are never found wanting. They may appear as the flippers of a whale or dolphin, as the wings of a bat, or as the burrowing implements of a mole; but they are always there. Also, most mammals are equipped with a tail of one kind or another, which in different types may serve very different purposes.

As we proceed, the wide variations within the mammalian class will become apparent; but at the outset, as we have seen, the most impressive variations are those of mere size. From the little shrew-mouse, measuring an inch and a half in length, to the huge

African elephant, which stands some twelve feet high, is a mighty leap; yet both these creatures are mammals. And so, too, is the eighty-foot whale, the monster of the deep. Yet the amazing variations in size and form and function represented by these two extremes have been accomplished during a period of no more than *ten million years.*

The great naturalist Huxley was the first to announce that the ancestor of all the mammals was probably of an insect-eating type; and since that announcement all accumulated data have tended to confirm it. In the hind feet of many primitive mammals, and even in the human infant, we note a limb-grasping adaptation which is evidence that the first mammals lived among the branches of the trees. Apropos of this, Huxley once remarked: "When a fond mother calls upon me to admire her baby I never fail to respond, by saying 'What a baby!' and, while cooing appropriately, I take advantage of an opportunity to gently ascertain whether the soles of its feet turn in and tend to support my theory of arboreal descent." Whatever the results of Huxley's sly researches with babies may have been, the theory of *arboreal descent* from an early ancestor long before *man* is now generally accepted for mammals, and we have reason to believe that the ancestral mammal form of Cretaceous time—from which radiated monkeys,

apes, and man—was not unlike the little tree-shrews that we now find in India and eastern Asia. More recently we have come to believe that the arboreal, or tree-living, habit among the ancestors of man was extremely remote. Osborn now maintains that man has walked erect and lived chiefly on the ground for an enormously long period of time.

Palæontology (or the zoology of the past) has enabled us to reconstruct the genealogy of the mammals with a fulness of detail that is impossible in the cases of the reptiles, amphibians, and fish. The earlier naturalists classified the mammals according to their differences in single structures. The classifications of structures among the mammals are infinite in number and are based upon a variety of individual characteristics—the class names being formed upon Greek or Latin roots. For example, some of the earlier naturalists classified the mammals according to their varieties of teeth, and even now we talk of bunodonts, lophodonts, or selenodonts. Or they founded a classification upon the number of toes that the creatures possess, and thus we discuss pentadactyls (five-toed animals), tetradactyls (four-toed animals) and so on. Or again, they proceeded upon the basis of locomotion, and we still speak of types as ambulatory (slow-moving), cursorial (swift-moving), saltatorial (leaping), fossorial (burrowing), natatorial

(swimming), and so forth. But such classifications, based on single characters, are largely artificial. The final or natural classification of mammals rests upon combinations of special characters of the teeth, the feet, the brain, and so forth. But the listing and definition of all these subclassifications would prove only confusing to the reader of a volume such as this; so we shall take into consideration only the broader and more important divisions of the mammal class. There are three main groups, which we classify in accord with the ways in which they care for their embryonic young. First and most primitive of these are the MONOTREMATA, or the egg-laying mammals, a single branch of which is now found in Australia and New Guinea, and which we may consider a connecting-link between the higher mammals and a reptilian type of Permian time (see Chart A, page 16). Second are the MARSUPIALIA, or pouched mammals—of which the opossum and the kangaroo are the most familiar specimens—which bring their young into the world in a very immature state. And third, and highest of them all, are the PLACENTALIA, so named because their unborn young are kept within the mother for a long period, and nourished through the placenta, or membrane surrounding the embryo.

This last and most important group is divided into ten orders that represent widely varying adaptive

radiations: (1) whales; (2) seals (marine flesh-eaters); (3) land-living flesh-eaters, such as lions and wolves; (4) insect-eaters, such as shrews and moles; (5) bats; (6) primates, including lemurs, monkeys, apes, and man; (7) ungulates or hoofed mammals, such as horses, cows, deer, etc.; (8) manatees (sea-cows); (9) rodents (rats, mice, rabbits, and squirrels); (10) edentates, or toothless animals, such as sloths and ant-eaters. These ten branches radiated from the primitive, insect-eating, tree-dwelling ancestor or ancestors to which Huxley was the first to point, and spread over the entire globe, until they began to suffer partial extermination at the hands of man some hundred and twenty-five thousand years ago.

Reconstructing the ancestral tree of the mammals, we find that it is, roughly, of this description (see Chart B, page 105): The first mammal-like reptiles make their appearance in early Permian time, and exhibit considerable variation in late Permian. In Triassic time we find the Cynodonta, reptiles from which the three main branches of the mammals are to spring: the Monotremes (or egg-laying mammals), the Marsupials, and the Placentals. The first Placentals appear in Upper Cretaceous time, and from them many sub-branches are thrust out: such as the primitive insect-eaters and flesh-eaters in Palæocene time; the first whales, bats, rodents, and edentates in Eocene time;

the first monkeys, anthropoids, and manatees in Oligocene time; and the first men in late Pliocene time. Meantime, we note that the Marsupials have branched out from the family tree at a point lower than the Placentals; and that the egg-laying mammals have taken their rise from an even lower point. The most active and fruitful period of this great evolution and wide radiation was the five or more million years that we allot to Upper Cretaceous and Tertiary time. Before we deal with this evolution and adaptive radiation, let us pause for a moment to contemplate the greatest single factor that gives the mammals an advantage over all their predecessors.

Sir Henry William Flower has stated, succinctly and lucidly, the position of mammals in the scale of Evolution: "Considered collectively, mammals, which did not make their appearance on the earth for some time after reptiles had existed, are certainly the highest group of the whole vertebrate subkingdom. This expression must not, however, be considered in too restricted a sense. In mammals, as in other classes, there are low as well as high forms; but by any tests that can be applied, especially those based on the state of development of the central nervous system, it will be seen that the average exceeds that of any other class, that many species of this class far excel those of any other in perfection of structure, and that

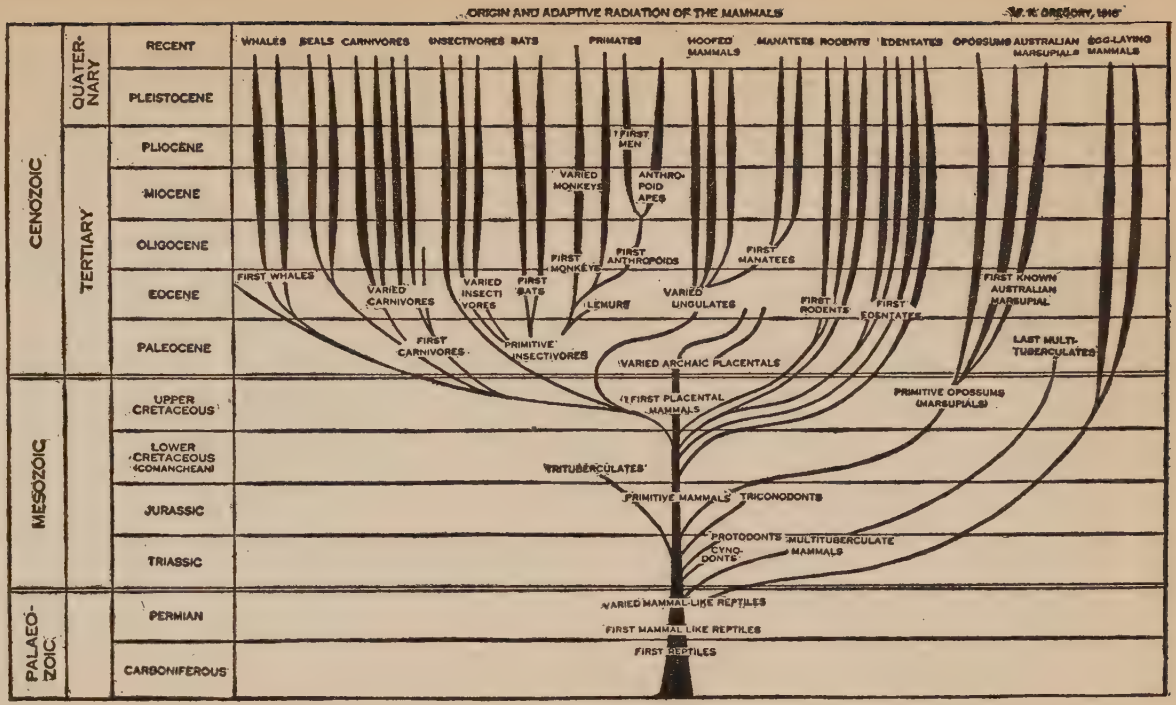


CHART B

Showing the very ancient origin and branching lines of ascent of the different kinds of mammals, the whales on the extreme left, the pouched marsupials and monotreme egg-laying mammals on the right, and in the centre the *Primates*, including lemurs, monkeys, anthropoid apes, and the ancestors of man.

it contains one form which is unquestionably the culminating point amongst organized beings."

What is the greatest advantage, then, that the mammals possess over other classes? Is it not obviously equipment for the care of their young? For does not this care result in opportunities for development which are not enjoyed by other creatures? This care varies, of course, as we go up or down the mammal scale; but it marks, to a greater or lesser degree, all branches of mammalian life, and in it we find the germinating cause of *family* existence as opposed to the *individual* existence of the earlier classes. And with the family begins the history of a new evolution, with which we are unconcerned in this chapter—social evolution.

So let us note the various ways in which the different groups of mammals care for their offspring. As we have seen, the lowest group of all is the Monotremata, or the egg-layers; and at first glance we might think that these creatures deal with their young precisely as do the birds. Nor are we wrong, up to a point. These primitive mammals make a nest in a burrow they have dug, and they lay eggs in that nest, just as would a bird or a reptile. But when their young are born, we see that these creatures are no reptiles, for they suckle their offspring with the oily secretion that oozes through large pores in their

glands. Here, then, even in this lowest type of mammal, now represented by the Duckmole (or *Ornithorhyncus*) of Australia, we see the mother performing an intimate, protective, nourishing act for her young, of which all non-mammals are incapable. A new relationship, a new factor of far-reaching importance, has been introduced into living society. In the act of the lowly Duckmole we see the first foreshadowings of that relation between mother and child which has always played so tremendous a part in the higher mammalian and human society.

When we reach the Marsupials, or the pouched mammals, we find a more highly perfected arrangement for birth, and a still more intimate relationship existing between mother and child. The Marsupials are represented by the opossums of America and by the kangaroos and wallabies of Australia, and, as regards the birth of their young, they represent a stage midway between the egg-layers and the Placentals. They are *viviparous*, that is, they are able to bring their young forth already alive from their bodies; but they are not equipped to deliver them as highly developed as are the Placentals, for they lack the blood-vessels whereby the higher mammals nourish the embryo before birth. The Marsupial mother hatches her eggs within her own body, but once having hatched them she must bring them forth into the

world in an imperfectly developed state; hence the familiar pouch of the kangaroo. The tiny offspring itself crawls into this pouch, where it can obtain nourishment from its mother's breast until it is sufficiently formed to venture out into the world upon its own legs. Here is a more highly perfected protective arrangement for the young than we have encountered before; but we find the highest stage of all in the third group of the mammal class.

This third and greatest group takes its name, as we have already noted, from the placenta, the vascular organ that joins the unborn child to the mother, making possible the transmission of nourishment to the embryo within the mother's body. It is the placenta that makes possible the retention of the unborn young for a longer period within the mother, and the consequently higher development of the young at the moment of birth. We have now reached the highest stage of all, as regards the care of the young, and the Placentals are, of course, the highest of the mammals. We see them all around us, in the dogs and cats that dwell in our houses, in the horses upon which we ride, in the cows that give us milk, in the lions and tigers that we hunt. And with all these creatures man himself must admit a remote kinship, for he is simply the highest member of the Placental branch of the widespread mammal class.

Having considered the great fundamental difference which marks off the mammals from all the other creatures of the earth, we are now prepared to deal with the evolution and adaptive radiation of this class, as we are able to trace it from Jurassic and Cretaceous time down to our own day. We have reached a stage in our history when the evidence for the knowledge we have is overwhelmingly abundant, and it is no longer a paucity but a wealth of material that embarrasses us. By rigorous selection we can deal only with the subject in its broadest lines, making our way through the age of mammals down to the age of one dominant mammal—Man.

CHAPTER VIII

THE AGE OF MAMMALS

IF you will look once more at the chronological chart, to which you have been referred so often, you will see that we have reached the next to the last chapter of our story. Indeed, we have reached the final chapter, for what we call the Age of Man is at best but an arbitrary division of the Age of Mammals; we are still living in that age, since man himself is a mammal, although infinitely superior to even his nearest kin. Looking at Chart A, you will notice, too, that the successive ages with which we have dealt are decidedly unequal in length, that they become steadily shorter as we trace their sequence from Archæozoic time down to the present day. Our first period is forty million years: that was the time required for the evolution of the bacteria, the algæ, and the other most primitive organisms. Our second period is more than half as long, and is the age of the invertebrates. The third period, marked by the amazing radiation of the reptiles, is thirty-five million years. And, last of all, the Age of Mammals, including the five hundred thousand years allotted to man, totals only three and a half million years. The end of

this last age has not come as yet, and we can only guess at what the final total will be; but the mathematical evidence of the chart gives us food for speculation. Of one thing at least we are sure: that the evolution of life has been steadily accelerated as the ages have past. And to what point that acceleration will reach, we can only guess.

The chapters of our history grow shorter as regards geologic time, but they grow longer and more bulky as regards the mass of material that they offer us. Regarding the thirty million years in which the first organisms were gradually evolving, we know comparatively little; at this stage we are compelled to make the most of every scrap of evidence. Regarding the Age of Mammals, our knowledge rests upon a bewildering mass of accumulated facts; we are embarrassed by the wealth of our material. The thorough historian is now able to indulge in minute details regarding Palæocene, Eocene, Oligocene, Miocene, and Pliocene life. He is able to write accurately of structural developments, of environment and radiation in relation to geography; he can trace migration routes and point to barriers; he can allocate the mammals to definite life zones and state the times of their appearances with certainty. But in this book we can permit ourselves no lingering over details; we must keep our feet firmly upon the highroad. So

let us move forward a few strides by considering briefly the modes and causes of Evolution as they are exhibited in the Age of Mammals.

At the outset we note that three chief modes of Evolution mark the developments of the mammals. Completely new characters may appear, either suddenly or as the result of a gradual process. Old characters may be modified, quantitatively or intensively, both as to form and as to color. All the characters of an organism may be modified or affected by a change of environment or by a change in the habits of the individual.

The mainsprings, if we may so express it, of these three modes of Evolution are changes in diet and changes in environment; and these changes result in an infinite number of combinations, for separate organs evolve independently in adaptation to their own particular functions. Cuvier believed that there was a correlation between the structure of the teeth and the structure of the feet in any given organism, and he held that it was possible to decide from a fossil foot, for example, what the structure of a fossil tooth, belonging to the same creature, would be. But we now know that there is no such law of correlation, and that such predictions as Cuvier believed in are impossible. Animals subsisting upon the same food, but living in different habitat (life) zones, may ex-

hibit similar teeth, while displaying markedly different locomotor organs; and animals living in the same habitat zone, but subsisting upon different kinds of food, will show similar locomotor organs, while differing widely as to teeth. This example of the independent development of two sets of "characters" will suggest the possibilities of twofold, threefold, or manifold adaptation.

To understand this phase of the subject, the reader should have a clear picture in his mind of the various habitat zones through which mammalian life is distributed, and the types of mammals that are found in each. They are twelve in number, and are as follows: Aerial (flying), bats; Aero-Arboreal (gliding), flying squirrels, etc.; Arboreal (tree-dwelling), lemurs, squirrels, sloths; Arboreo-Terrestrial (transitional stage), gorillas and certain monkeys; Terrestrial (walking, running, jumping), many insect-eaters, baboons, running types, kangaroos, jumping rodents; Terrestri-Fossorial (transitional stage between the terrestrial types and the diggers), a great variety of clawed mammals; Fossorial (digging), moles, etc.; Terrestri-Aquatic (transitional stage between land and water), shrews, beavers, polar bears, hippopotami, etc.; Aquatic Fluvial (living in fresh water); Aquatic Littoral (living along the shore or in estuaries), sea-otters, sea-cows, sea-walruses; Aquatic

Pelagic (exclusively marine), whales; Aquatic Abyssal (living at, or diving to, great depths), fin-back whales.

The Arboreal was the first of these zones in which mammals appeared, and from there they radiated into all the others, with consequent adaptations which led to body forms and locomotor organs similar to those that had previously been evolved by the fishes, the amphibians, and the reptiles. For instance, we note resemblances between bats and pterosaurs, between the gliding mammals and the flying lizards, between the tree-dwellers and the chameleons, between the Terrestri-Aquatic types and the lizards and turtles.

We have seen that the mainsprings of adaptation and variation are changes of food and changes of environment; and that these result in an infinite variety of mammal types. At once the question arises whether these adaptations are the result of chance or of law. Let us see what Professor Osborn has to say regarding this question. In "The Origin and Evolution of Life" he writes:

"The adaptations which arise in the search of many varieties of food and in overcoming the mechanical problems of locomotion, offense, and defense in the twelve different habitat zones are not fortuitous. On the contrary, observations on successive members of families of mammals in process either of

direct or reversed or of alternate adaptation admit of but one interpretation, namely, that the evolution of characters is in definite directions toward adaptive ends; nor is this direction limited by the ancestral constitution of the heredity-chromatin as conceived in the logical mind of Huxley. . . . It is true that the variations of the organism are in some respects limited in the heredity-chromatin, as Huxley imagined; on the contrary, every part of a mammal may exhibit such plasticity in course of geologic time as enables it to pass from one habitat zone into another, and from that into still others, until finally traces of the adaptations to previous habitats and anatomical phases may be almost if not entirely lost. The heredity-chromatin never determines beforehand into what new environment the lot of a mammal family may be cast; this is determined by cosmic and planetary changes, as well as by the appetites and initiative of the organism."

In passing, it should be noted that all the effects of migration from one habitat zone to another may be produced without any movement upon the part of the animals themselves. There may be what one scientist has called the "migration of the environment itself." In other words, a mammal family may dwell in a region to which they have perfectly adapted themselves, only to find that the environment has

completely changed, or "migrated." In that case they can choose between two courses: either they can adapt themselves to the new environment that has been forced upon them, or they can migrate themselves in search of a region that reproduces the conditions to which they are accustomed. Professor Osborn remarks on this point: "Thus if we imagine a family of mammals residing continuously in the region now known as South Dakota, the early humid environment has migrated to quite a different part of the American continent, and an entirely new, arid environment has come in. Sometimes mammals and their environment migrate together. This was certainly the case during the Glacial Period, when physiographic conditions, fauna and flora all moved southward together before the advance of the ice-sheet, and again moved northward together as the ice retreated."

When we turn from the *modes* to the *causes* of mammalian evolution, we turn from a field concerning which we have considerable substantial data to one in which speculation is still rife. Regarding the activity of physicochemical agents we are still very much in the dark, but there are a few statements that we may make with assurance. For example, the basically similar physicochemical organization of fishes, amphibians, birds, and mammals may be held respon-

sible for the fact that we find among the mammals a repetition of the forms evolved by the lower orders in similar environments. And we are sure that increasing complexity of structure must reflect an increasing complexity in the physicochemical constitution. The difference is that we can see the one, but cannot see the other: the results are visible, the causes are hidden. Any one can see that the giraffe, which browses upon the tree-tops, has an exceptionally long neck; but the *why* of this elongated neck is another, and not so obvious, matter. Lamarck believed that it was due to the inheritance of structural modifications resulting from the animal's habit of stretching its neck in quest of nourishment. Darwin, on the other hand, found his explanation in the law of selection: the individuals and races born with the longest necks were, in his opinion, the best fitted to survive and consequently did survive. And, in this instance, it is probable that Darwin's conclusion was correct, for here is a case where a structural characteristic is of obvious value in the struggle for existence. But what of the changes of bodily form that appear to have no value in this struggle? What is the cause, for example, of long-headedness and short-headedness in men, of a long-fingered form and a short-fingered form? In these instances we can point to no selective survival values. But it has been discovered recently

that the proportions of the fingers, as well as other parts of the body, are apparently affected by the activities of the pituitary gland, which lies at the base of the brain. Overactivity of this ductless gland apparently results in broad, short fingers; while underactivity apparently results in fingers that are slim and tapering. We stress the word *apparently* here for the reason that we have no final proof, as yet, whether we are dealing with a mere coincidence or with a case of direct causation.

From the above it will be seen that this question of *causes* is still a troubled one; and it is clear that the discussion of such a question has little place in an elementary book of this kind. So, fascinating as speculation might prove, we shall move forward on to surer ground.

Since Buffon there has been no doubt that the fate of mammals, as indeed of all living creatures, is intimately bound up with their environment. The great Frenchman, who wrote in the middle of the eighteenth century, pushed his theories to untenable lengths, but he did perform the very great service of linking zoology with geography, and when he did that he pointed the way to one of the most profitable lines of research. Buffon, working from such observations as that the quadrupeds of North America were smaller in size than those of Africa and Eurasia, for-

mulated the theory that environment exercises a direct action upon the organism. To his mind, environment was the great causal factor in all modifications of animal forms; and he went so far as to hold the more or less intense action of the Sun responsible for the different shades of skin coloration that we find in the various races of mankind.

We have gone far beyond Buffon to-day, and we now know that Environment is only *one* of the *four** causal factors that we have to take account of in our evolutionary studies; but our debt to the pioneer in this field is none the less for that. He showed the way, and now when we study the evolution of mammals we take into consideration all the geologic changes that have occurred during Tertiary time, the Age of Mammals. These changes are less marked than those which took place in Mesozoic and Palæozoic time—for the Earth's surface and its climate have been growing more and more stable during the past three million years—but the changes have been quite tremendous enough. It was Eocene time, for example, that saw the mighty Rockies of America and the eastern European Alps rear aloft their heads; Oligocene time witnessed the rise of the Pyrenees and the snow-capped Alps of Switzerland; and in the Miocene epoch the massive Himalayan chain arose.

* The other causal factors are Life Enviroment, Habits of the Organism, and Heredity.

Following these huge shiftings of the Earth's surface, there came the glacial period, which affected Europe, Asia, and America, leaving only Africa untouched, and resulting in the vast migration to which we have previously alluded. This Age of Ice resulted from the geologic changes we have mentioned. The elevation of land over wide areas in Europe, Asia, and America caused an immense precipitation of moisture which formed numerous glaciers; and as these crept down the mountainsides and spread across the level lands, the mammals were forced to flee before them. Following the Glacial Period we note a post-Glacial Period, in which certain of these elevations subsided, with the result that the climate grew more temperate, the ice gradually disappeared, and flora and fauna adapted to the temperate zone spread over the lands that had previously been uninhabitable. But we are running ahead of our story; so let us turn back to the very beginning of the Age of Mammals, and there make a new start, equipped with the knowledge that we have regarding the modes of mammalian evolution and the intimate relation between mammals and their environment.

At the close of Cretaceous time (see Chart A, page 16), some three and a half million years ago, the continents and the seas were still swarming with the huge reptiles that had survived the struggles of the previ-

ous age. Already the ichthyosaurs and the plesiosaurs, monsters of the deep, had played out their rôles upon the planet and entered into the limbo of extinct forms; but the giant sea-lizards still flourished, and with them the giant sea-turtles. In Europe and in the Rocky Mountains of North America still lived a variety of dinosaurs: the giant, herbivorous "duckbills" (Iguanodontia), the horned Ceratopsia, the armored ankylosaurs; and, preying on the grass-eaters, there were the formidable flesh-eating megalosaurs of the *Tyrannosaurus* type. A number of the smaller, swift-moving dinosaurs had also survived.

All these reptiles had reached the height of their development and their specialization: the brilliant afternoon of the reptilian day had been reached, a sudden twilight was about to fall. Yet the signs of this approaching dusk could not have been numerous, for the reptiles were living in what must have seemed an ideal environment. Huge palms and tall sequoias, lush bananas and fig-trees covered the land; the vegetation was all typical of the southern temperate zone. Life must have seemed peculiarly well-favored in those rich forests, yet the end was near: the great reptilian dynasties were drawing close to extinction. Palæocene time was to see the rise of a new class of animal rulers, of a class whose first mem-

bers were even now living obscurely in the realms of the lordly reptiles. From the small, unspecialized, warm-blooded quadrupeds, now taking to a life among the tree branches, were to spring the future rulers of the land and sea.

What was the world-wide cause that wiped the giant reptiles from the surface of the Earth, and cleared the way for the evolution of the mammals? We do not know. On this point Professor Osborn observes: "Reptiles are so sensitive to temperature that it is natural to attribute this extinction to a general lowering of temperature, or refrigeration, but the flora shows no evidence of this either in Europe or America; nor is there evidence of any great geographic cataclysm on the surface of the earth, for the plant-life transition from one age to the other in the Rocky Mountain region is altogether gradual and gentle." And later, having dealt in detail with the transitional stages of plant life in these ages, he concludes: "The existence of this continuous similar flora . . . through the transition from the Age of Reptiles into the Age of Mammals is strong evidence that the cause of the extinction of the Reptilia is not to be sought in a change of flora or in a lowering of temperature."

We do not, then, know what the cause was that brought about the extinction of the dinosaurs and

their kin, but we are in no doubt about the effect: the giant reptiles disappeared from both the land and sea.

From various rock formations and deposits in various parts of the world we can learn of the passing of the reptiles and of the earliest mammalian life that appeared upon our planet. These are all classified, named, and accorded their proper positions in geologic time: specialists write monographs upon the Laramie and Lignitic beds of Montana, the Thanetian formation of Basal Eocene Europe, the Puerco formation of New Mexico. But the general reader could only be confused by a discussion of these sources of our evolutionary knowledge; so we shall attempt to do no more than to recount as simply as possible the story that we have learned from these various rock formations.

First of all, however, we must refresh our knowledge of the chronological divisions of the period with which we are dealing, for otherwise we shall be using words that mean nothing to us. If you will look again at the Chart A (page 16), you will note that the Age of Mammals and the Age of Man form together what is known as the Cænozoic Era (this name meaning "The Age of Recent Life"). This era is divided into the Tertiary Period and the Quaternary Period (in other words, the third and fourth periods in the

history of life), one being identical with the Age of Mammals, the other identical with the Age of Man. This is, however, an arbitrary division, for man, as we know, is simply the highest of the mammals. Now these two periods are subdivided into six epochs; and it is important that we should realize the significance of each of these epochs as a chapter in our general history. Beginning with the oldest, and working down toward the present, we may list and explain them as follows:

Eocene.—This epoch is marked by the extinction of many archaic types of mammals that flourished in the Age of Reptiles, and by the appearance, toward the close of the epoch, of a number of the ancestors of the modern mammals.

Oligocene.—In this epoch we note the disappearance of many of the primitive mammals, and the advent of a number of existing mammalian types.

Miocene.—This epoch is characterized by an increasing number of mammals resembling existing forms.

Pliocene.—This is the epoch of extensive modernization, in which we find representatives of all the existing mammalian families and orders, but few or no representatives of existing species.

Pleistocene.—This epoch is marked by the last glacial period, by the extinction of earlier forms all over

the world, and by the appearance of the great majority of recent mammalian forms.

Holocene or Recent.—In this epoch we witness the world-wide destruction and elimination of mammals at the hands of men.

With this outline in mind, we may proceed to note briefly something of the history that may be read in the deposits and formations of the earth's crust, remembering that these lie one on top of another and that the deeper we go the further we go back in time. What, for example, do these formations tell us of Basal (earliest) Eocene life in western North America —Colorado, Wyoming, Montana, and the Dakotas? We learn that during the Age of Reptiles, in Upper Cretaceous time, this region consisted largely of open country that was cut through by numerous waterways. Then there grew up dense forests, destined to form beds of coal or lignite in their decay; and in earliest Eocene time these forests were dotted with vast swamps and bogs, among which there flourished lizards, alligators, and swamp turtles. The swamp-lizard survived from Cretaceous time, but early Eocene life was generally characterized by the disappearance of those giant reptiles that had been the mighty contemporaries of the lizard, itself now upon the eve of its extinction. At this stage we find a certain number of marsupials and other primitive mam-

mals, but we discover no mammals that can be considered members of any of the modern families. These do not appear until the Lower Eocene, the subdivision subsequent to the Basal Eocene. All the mammals of the earlier period are survivors of the obscure mammalian life which was gaining a foothold in the world during the era of reptilian domination.

The Basal Eocene in Europe offers us specimens of insect-eating mammals, certain mammals resembling our modern lemur, a few hoofed animals, and a number of flesh-eaters. In the rivers there were fishes similar to the garpikes and bow-fins that are now found in our North American rivers, while the marshes and streams were alive with various types of crocodiles and turtles. The climate was temperate, and the most common trees were luxuriant palms, cinnamons, and laurels.

Slightly earlier, in New Mexico and Montana, we find the small archaic mammals that were evolving from ancestors who lived during the reptilian age. Among these we discover two orders of hoofed mammals that are now extinct, both of which were plant-eaters. At one time it was thought that the direct ancestors of the modern mammals could be found in the animals of this period, but it can now be stated with conviction "that not a single representative ancestor of any *existing* order of mammals is certainly

recognized in this assembly." For such ancestors we must turn to a period considerably later in geologic time.

The stem forms of the existing mammalian orders —the ancestors of the modern flesh-eaters, insect-eaters, whales, lemurs, bats, rodents, armadillos, and ant-eaters—have all been traced back to the close of Eocene time; and in the Lower Eocene we have found the ancestors of the modern horse and various cloven-hoofed animals. The primitive horse, or *Eohippus*, of lower Eocene time, was a four-toed animal; and the evolution of this creature into the three-toed ancestor of the modern horse affords a particularly happy illustration of adaptive transformation. Mammalian evolution and adaptation are largely the result of very gradual changes in proportion; it required, for example, at least a million years for the primitive horse to lose one of its toes. In the face of such evidence as this, we find ourselves far from all theories based upon sudden and chance changes in character and proportion. In the evolution of the horse, too, we can study the adjustment to speed of the limb segments. The upper segments gradually grow shorter, while the lower segments grow longer; this being just the reverse of what occurs among the ancestors of the slow-moving elephants.

The adaptation of the feet and teeth of all mam-

mals to their environment is so amazingly close that we are enabled, to a great extent, to write the climatic and physiographic history of the Tertiary Epoch from the evidence of teeth and feet alone.

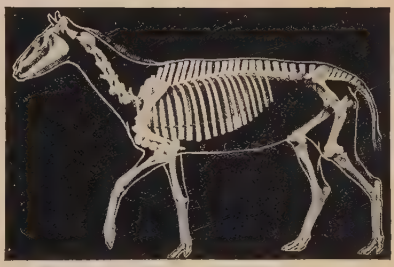
On this point Professor Osborn writes: "Through the successive adaptations of the limbs and the sole of the foot and the adaptations of the teeth, which are most delicately adjusted—the former to impact with varying soils and the latter to the requirements of the consumption of various forms of nourishment —we may definitely trace the influences or rather the adaptive responses to the habitat subzones, such as the forest, forest-border, meadow, meadow-border, river-border, the lowland, the upland, the meadow-fertile, the meadow-arid, the plains, and the desert-arid. This mirror of past geography, climate, evolution of plant life in the anatomy of the limbs and feet is one of the most fascinating fields of philosophic study."

Our record of mammalian evolution throughout the three million years of Tertiary time is now remarkably complete, and we can trace the development of many flesh-eaters and of the majority of the hoofed animals and the rodents, with only a few breaks. As a result of the full and extensive evidence available, we have arrived at the *modes* of mammalian evolution noted early in this chapter.

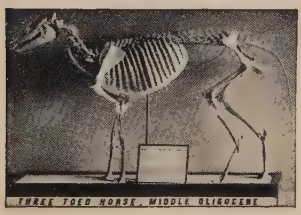
C

F

B



E



A

D

Five stages in the evolution of the horse. *A, B, C,* three-toed horses of middle and upper Oligocene time, in ascending order of size. *D, E,* three-toed fossil forest-living, browsing horse (*Hypohippus*) of Pliocene time. *F,* slender three-toed plains-living horse (*Hipparion*) of Pliocene age. *After Osborn, American Museum*

Reproduced through the courtesy of the Hispanic Society of America.

Four views of a Neanderthal skull from the cavern La Chapelle-aux-Saints. *A*, left side. *B*, front. *C*, cranium from above. *D*, cranium from back. *After Boule and Obermaier.*

Jaw of Heidelberg man, believed to be ancestral to the Neanderthal man. *After Schoetensack and Osborn.*

It is impossible here to deal in any detail with the mass of information we possess regarding the mammalian life of Tertiary time; the best we can do is to indicate its development along the broadest lines. Past chapters have revealed to us the relation existing between hunter and hunted in the living world, and the evolutionary effect which the one has upon the other. During Tertiary time we find this relation as prominent as ever, and its effects just as notable; we find the flesh-eaters perfecting their mechanisms of offense, pursuit, and capture, while their victims are developing powers of defense or powers of escape. The land-dwelling flesh-eaters with which we are familiar fall naturally into two general divisions: the cat-like and the dog-like. Among the first are the lion and the tiger, the hyena and the leopard; among the second are the wolf and the bear, the fox and the otter. The ancestors of all these modern animals ranged the land, while the seals and walruses took to the sea, and their predatory activities caused the other mammals to take flight in various directions and develop various defenses. Some continued to dwell in the tree branches, increasing their speed and their agility. Others took to the rivers, still others to the sea. Certain small creatures learned to burrow beneath the ground, and others adjusted themselves to a wholly nocturnal existence, bestirring themselves

only when their enemies were asleep. Others again, such as the hedgehog and the porcupine, found comparative security in defensive coverings or, as the skunk, in odors. The hoofed animals spread far and wide, developing speed in the majority of instances; but in others—such as the hippopotamus and the rhinoceros—developing bulk. The rhinoceros, too, grew a horn for purposes of defense, just as the elephant grew tusks.

But, as we have stated before, we must look upon the struggle for existence as only one of the causal factors in the evolution of forms and functions; we must not forget the other evolutionary complexes noted earlier in our history:

The changing *heredity*, insensibly but gradually going on in course of time.

The changing *physical environment*, of climate, heat and cold, humidity and aridity, elevation of land or sea.

The changing *living environment*, of plant and animal life, of friendly and hostile forms, of comrades and competitors.

The changing *habits of life*, preference for one mode of feeding or another, for a water, or a land, or a tree habitat.

Meantime, in the midst of this vast life struggle, the ancestors of the anthropoid (man-like) apes and

the unknown ancestors of man were slowly evolving. Let us make no mistake at this point about man's relation to the monkeys or the apes. Despite all that has been written upon the subject, there are still many worthy persons who believe that the prime tenet of the evolutionists is the belief that we are *directly descended* from such simian creatures or monkeys as those we see chattering within the cages of our zoos. Now the evolutionists say no such thing. What they do say, and what they have proved beyond shadow of scientific doubt, is that we are descended from a common, unknown, ancestral stock which also gave rise to the gibbons, gorillas, orangs, and chimpanzees. At what period man branched off from the common anthropoid stock we cannot say with absolute definiteness, but it was certainly before the Pliocene age, probably somewhat later than the appearance of the earliest gibbons in the Miocene age. From this it is obvious that our relation to the existing apes and monkeys is no closer than that of extremely distant cousins; with them we can claim a common ancestry, but our paths and theirs diverged long, long ago.

So all talk of a "missing link" is rather misleading, for scientists are not seeking a "link" that would occupy a genealogical position between the lowest man and the highest ape; but they are seeking to dis-

cover the precise character of our anthropoid ancestors, from which both the apes and ourselves are descended. It may be that fossils of these ancestors are now buried deep beneath the seas (for we must remember that the waters on the earth's surface have shifted greatly in the past) and that we shall never find them; but great hope is held out of the investigations now being made in Asia, which continent many anthropologists believe will be found to have been the radiating centre of the human race. In southern Asia we have already found primitive representatives of two of the four existing types of anthropoid apes (the gibbon and the orang), besides another line known as the *Dryopithecus*, or forest ape; and it is probable that the same location may yield us traces of the ancestors of truly human types.

Our account of the Pliocene age must close with a very brief mention of one of the most startling and unexpected discoveries of recent years, namely, that man existed even in the Pliocene age—man capable of fashioning flint implements for a variety of useful purposes, man with a knowledge of the use of fire. This discovery was made, not in southern Asia, as we might have expected, but on the eastern coast of England not far from Norwich, in a bank of gravel and sand near the little hamlet of Foxhall. It was so unexpected that it was received with incredulity by

British scientists, with the single exception of Sir Ray Lankester. The discoverer, Mr. J. Reid Moir, awaited the support of Professor Osborn and of the French archæologists, Henri Breuil and Louis Capitan, to confirm the epoch-making results achieved by his excavations. Only a few flint implements were found, some of them charred by fire, but they sufficed to confirm the theory advanced by Professor Osborn that man has had a long and independent line of ancestors of his own, and that the use of tools and implements began before the close of the Age of Mammals and long before the Chellean age, which was the starting-point of our realization of the great antiquity of man.

Avoiding the controversial aspects of these questions, we shall proceed, in the two chapters left us, to follow as accurately and briefly as possible the rise of the anthropoids, culminating in the life of man upon our earth—solely according and in keeping with the actual knowledge we have culled since 1859.

CHAPTER IX

THE RISE OF MAN

IT seems fitting that we should begin this chapter on the rise of man with a quotation from Buffon, the first French evolutionist, who was one of the pioneers in the application of the modern evolution theory. So long ago as 1749 Buffon wrote: "The first truth that makes itself apparent on serious study is one that man may perhaps find humiliating; it is this—that he, too, must take his place in the ranks of animals, being, as he is, an animal in every material point." This was written more than one hundred and seventy-five years ago, yet popular prejudice is so slowly uprooted that even to-day legislators are militating against the teaching of evolutionary truths in our schools and universities, and in some States are actually forbidding the inculcation of such "dangerous" doctrines.

Buffon was hampered by the clerical power of his age and country and by his own religious bias; but despite the wavering of his opinions he did extremely valuable work in the study of the orang, one of the ape family of Borneo, and he cleared the way for his successor, Lamarck, who came out boldly with the

statement that man was descended from an animal like the anthropoid apes. This great Frenchman laid emphasis upon man's erect position, noting that this position was occasionally assumed by the apes themselves; his argument was that certain apes had gradually learned to walk upright, with consequent physical modifications, that they had mastered the other animals, spread over the face of the earth, and developed the power of communicating ideas by means of speech.

On the heels of Lamarck, archæologists of France came forward with evidence of man's great antiquity, based on discoveries in the caves of southern France and Belgium. About twenty-five years later (1856) the discovery of an entirely extinct race of men, named the "Neanderthal," furnished the evolutionists with new material. Discoveries of other types of primitive men have followed down to our own day, discoveries that have made us constantly lengthen our estimates of the age of man.

While the anthropologists were working along their own lines in the effort to trace the descent, or rise, of man, the archæologists, beginning as far back as 1700, were accumulating evidence that races of men had lived and fought and conquered nature by the use of tools long before the dawn of Record History. In the middle of the eighteenth century was advanced

the theory that man in his most primitive period was dependent upon stone alone for his weapons and his tools, that this stone age was followed by an age of bronze, and that bronze gave way to iron in a later period. In 1840 a treatise on prehistoric stone implements was published, showing the way for Neolithic and Palæolithic (see Chart A, page 16) research. The discoveries of primitive human bones and prehistoric flint implements multiplied apace, and gradually the life and work of the early cave-dwellers were revealed to the world. Soon there was abundant material for classification, and Sir John Lubbock divided prehistory into four great periods, basing his divisions upon the type of implements used in each. Earliest of all was the *Palœolithic Period*, in which man used chipped or flaked flint implements and other rudely shaped stone tools, at a time when the mammoth, the cave-bear, and other now extinct animals roamed the world. Then came the *Neolithic Period*, or polished Stone Age, when the primitive implements were improved but no metal save gold was known. In the third epoch copper and bronze supplanted stone as the material for all weapons and cutting implements. Last of all, iron superseded bronze for arms of all sorts, while the softer metal was still used for ornamentation.

This rough classification has since given way to

more precise divisions of human prehistory, but it is still useful to keep in mind as a general outline. Before we come to use this outline, however, we must review what we know regarding the rise of the man-like apes and man himself.

From recently collected evidence we now have reason to believe that the common ancestors of man and the anthropoid apes probably originated in the forests and on the plains of central Asia, and migrated from that location into western Europe and northern Africa. So early as Oligocene time (see Chart A) we find in northern Egypt traces of a possible forerunner of the great man-like apes; this creature resembled the gibbon in many respects. Early in Miocene time the true tree-dwelling gibbons made their appearance in Europe, where they continued to live throughout Pliocene time, wandering northward into the region that is now known as Germany. Another ape, known as *Dryopithecus*, including a number of species resembling the modern orang and other anthropoids in the formation of its teeth and the Piltdown man in the structure of its jaw, reached southern France in the Miocene epoch; and a third type, whose teeth apparently bore a distant resemblance to those of man, has left its record in a Lower Pliocene formation of Germany. In the Pliocene of Asia still another type has been found, obvi-

ously related to the gibbon, the gorilla, and the chimpanzee, and resembling man in certain of its teeth.

To none of these types of apes can we point directly and say with certainty: Here is the ancestor of Man. Neither among them nor among the four living forms of anthropoid apes (gibbons, chimpanzees, gorillas, and orangs) do we find evidence of direct ancestral relationship to man, but we do find unmistakable evidence of a descent from a common ancestry with man—undeniable proof of that geologically remote cousinship which we have previously mentioned. Comparing the anatomy of modern man with that of the modern ape, we find proof enough of remote relationship; but when we compare the ancient Palæolithic races of man with the apes our conclusions are even more certain; for example, the Neanderthal man is more ape-like than we are, and hence it may be called a "missing link." In fact, properly to understand the anatomy of the men of the Old Stone Age, we must have a clear view of the anatomical features of the living man-like apes.

Most primitive of these apes is the gibbon, which was probably closer than any of the others to that primitive insect-eating creature (tree-shrew or Tupaia) from which the mammals took their rise. Its primitive nature is evidenced by the structure of its skull and by the character of its teeth, but the great length of

its arms is an example of extreme specialization for an arboreal life. With a short face, like all the other apes, the gibbon's straight profile is closer to man's than that of any of its fellows. Its physical accomplishments are not limited to feats of acrobatics among the trees performed by means of its very long arms, for when it is on the ground it is able to walk erect for a short distance; and this is a fact of prime interest.

In the orang of Borneo we find limbs that are less well adapted to a life among the tree branches, but still of a more arboreal type than those of the chimpanzee or the gorilla. When we come to the chimpanzee, we find the same bony ridges above the eyes that distinguish certain of the primitive races of man, the same type of lower jaw, and the same rows of protruding teeth. The chimpanzee walks erect for short distances, and when he does so his arms reach well below his knees, whereas among all the races of mankind the arms reach only half-way to the knees. We note that in both the arms and legs of the chimpanzee the upper bones are comparatively long and the lower bones comparatively short, this proportion being an inheritance from a tree-dwelling life; while the legs and arms even of the fossil Neanderthal men exhibit precisely the opposite proportions and are adapted to a walking life upon the ground. Another

characteristic exhibited by the chimpanzee, in common with all the apes, which is in contrast to that of man, is the grasping power of the big toe of the foot, accompanied by a corresponding lack of power in the thumb of the hand; whereas among men, even the most primitive, this grasping power lies only in the thumb and is lacking in the toe.

Turning to the gorilla, we find physical modifications that are due to a semiarboreal, semiterrestrial life, and to the use of skull and jaws as weapons of offense. The head has grown longer because of the forward thrust of the muzzle, and the body has grown thicker and heavier as a result of a partial descent from the trees.

These many differences in limb structure between the apes and man prove that man is not a descendant of the tree-living apes, as Lamarck believed, but has a long line of erect-walking ancestors of his own. Far back of these erect-walking ancestors man may have passed through an arboreal or tree-stage of existence, for protection from his enemies.

But in tracing these structural changes and contrasts we are not touching upon the one great thing that divides man from the apes—the increase in brain power. How did this increase occur? By what miracle did the ancestors of man come to surpass their lowly rivals in mental abilities and potentialities?

First of all, we may safely say that this great forward step was accomplished by no sudden step, for we know that that is not the way of Nature; we know that this modification of intelligence, like all others, must have been a direct response to the evolutionary causes, for example, that we have already defined. The brain is so delicate, mysterious, and baffling an organ that any increase in its power seems more remarkable than the increase in the power of a limb, for example. Yet we must seek our explanation in the same general factors if we are to arrive at the truth. On this point we may profitably borrow at some length from Elliot Smith, as quoted by Professor Osborn, who writes:

"As regards psychic evolution, Elliot Smith observes that the arboreal mode of life of the early [*i. e.*, most remote] ancestors of man developed quick, alert, and agile movements which stimulated the progressive development of the posterior and lateral portions of the brain. The sense of smell had been well developed in a previous terrestrial life, but once these creatures left the earth and took to the trees, guidance by the olfactory sense was less essential, for life amidst the branches of the trees is most favorable to the high development of the senses of vision, touch, and hearing. Moreover, it demands an agility and quickness of movement that necessitate efficient motor centres

in the brain to co-ordinate and control such actions as tree life calls for. The specialization of sight awakens curiosity to examine objects with greater minuteness and guides the hands to more precise and skilled movements.

"The anatomy of man is full of remote reminders of this original arboreal existence, which also explains the very large and early development of the posterior portions of the brain, in which the various senses of sight, touch, and hearing are located.

"The first advance from arboreal to terrestrial life is marked by the power of walking more or less erect upon the hind limbs and thus releasing the arms; this power is developed to a greater or lesser degree in all the anthropoid apes; with practice they become expert walkers. The additional freedom which the erect attitude gives to the arms and to the movements of the hands and the separate movements of the fingers is especially noticeable in the gibbon. The cultivation of the hand reacts upon the further growth and specialization of the brain; thus the brain and the erect attitude react upon each other. In the gibbon there is a marked increase in the size of those portions of the brain which supply the centres of touch, vision, and hearing.

"Discussion as to how the ancestors of men were fashioned has chiefly dealt with the rival claims of

four lines of structural evolution: first, the assumption of the *erect attitude;* second, the development of the *opposable thumb* [*i. e.*, the ability to bring the thumb against each of the fingers]; third, the *growth of the brain;* and fourth, the acquisition of the *power of speech.* The argument for the erect attitude suggested by Lamarck, and ably put by Monro in 1893, indicates that *the cultivation of skill with the hands and fingers lies at the root of man's mental supremacy.* Elliot Smith's argument that the steady growth and specialization of the brain itself has been the chief factor in leading the ancestors of man step by step upward indicates that such an advance as the erect attitude was brought about because the brain had made possible the skilled movements of the hands.

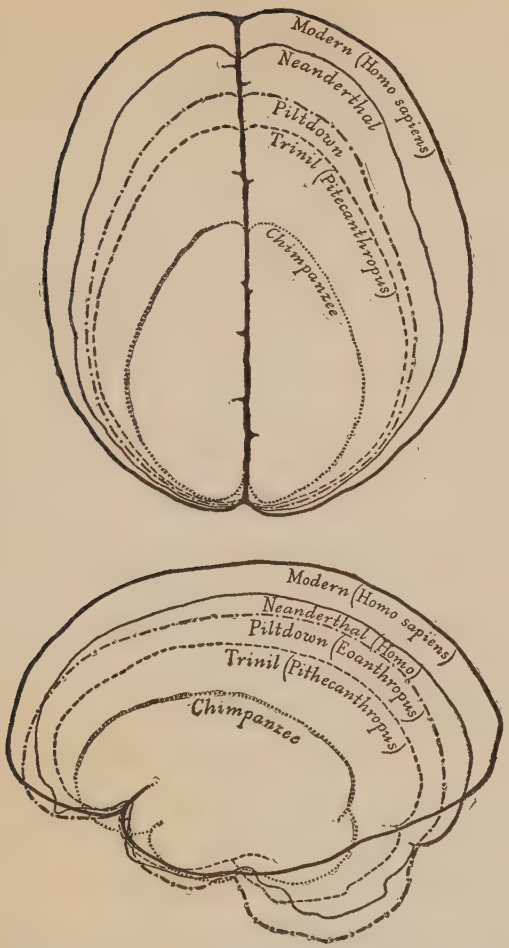
"The true conception of prehuman evolution, which occurred during Miocene and Pliocene times, is rather that of the coincident development, namely, of these four distinctively human powers. It appears from the limb proportions in the Neanderthal race of the Stone Age that the partly erect attitude and walking gait of the remote ancestors of man were assumed much earlier in geologic time than we formerly imagined.

"The intimate relation between the use of the opposable thumb and the development of the higher mental

faculties of man is sustained to-day by the discovery that one of *the best methods of developing the mind of the child is to insist upon the constant use of the hands*, for the action and reaction between hand and brain are found to develop the mind. A similar action and reaction between foot and brain developed the erect gait which released the hand from its locomotive and limb-grasping function, and by the resultant perfecting of the motion of thumbs and fingers turned the hand into an organ ready for the increasing specialization demanded by the manufacture of flint implements.

"This is the stage reached, we believe, in *late Pliocene* times [see Chart B, page 105], in which the human ancestor emerges from the age of mammals and enters the age of man, the period in which the *prehistory of man* properly begins. The attitude is erect, the hand has a well-developed opposable thumb, the centres of the brain relating to the higher senses and to the control of all the motions of the limbs, hands, and fingers are well developed. The power of speech may still be rudimentary. The anterior centres of the brain for the storing of experience and the development of ideas are certainly very rudimentary."

The above quotation gives us the theoretic key to the brain-evolution which has raised man so far above all his fellow mammals. We see that this psychic



The increasing size of the brain as seen from above (upper) and from left side (lower). The various dotted lines represent the brain of the chimpanzee, of the Trinil ape-man (*Pithecanthropus*), of the Piltdown man (*Eoanthropus*), of the Neanderthal man (*Homo neanderthalensis*), and of the modern man (*Homo sapiens*).

development, like the more obvious anatomical developments, has been due to the actions of the animal itself in relation to its environment. Use of the hands and feet for highly specialized purposes reacts upon the brain with a resultant increase in mental power, which leads again to further physical specialization, and finally to the creation and employment of tools for various tasks that have been suggested and made possible by this mental development.

Precisely when the first implements were fashioned by primitive man we cannot say. We are in possession of flints (*i. e.*, eoliths) so crude that experts cannot agree whether their shape is the result of human artifice or of accident; but it is highly probable that even before the first stones were shaped for use men made use of sticks and the broken branches of trees. It is probable, too, that the first implements were used as weapons, for we find that apes sometimes wield branches effectively, and the case of monkeys hurling stones at one another is far from unfamiliar. So it may be assumed that the implements of peace and progress took their rise from the first weapons which men, with dawning intelligence, found ready to their hands: from a broken branch to a fashioned club is a long stride, but it is a consistent one. And so, too, we may easily comprehend how the stone that was first used as a missile might be soon used as a hammer

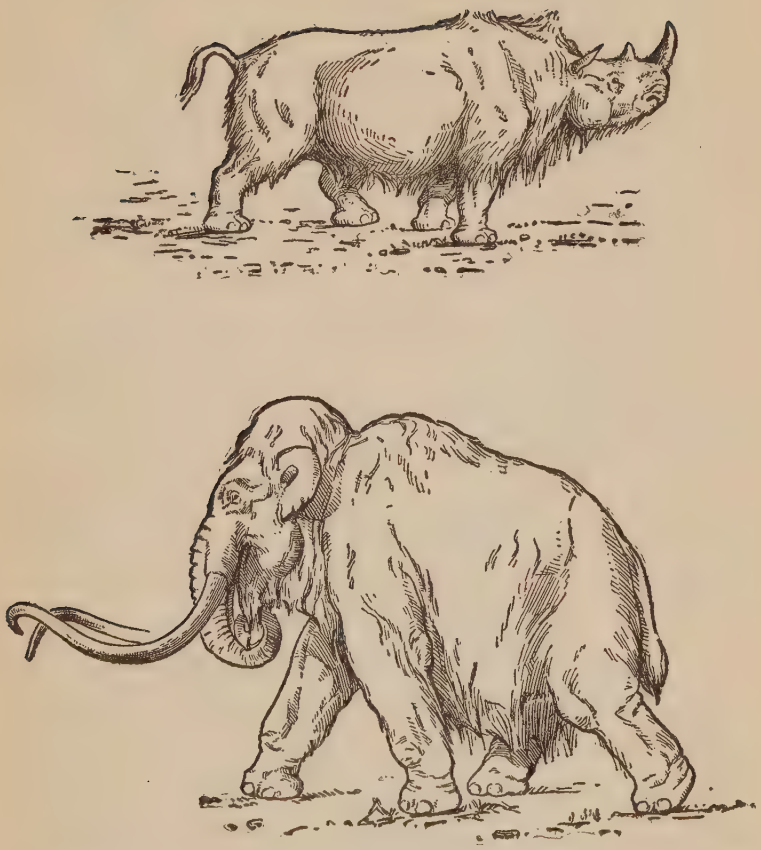
for a purely domestic purpose. It was when some creature first sharpened the edge of one stone with another that the age of man as a tool-using animal really began.

It was, then, in late Pliocene times, so far as we now know, that the human ancestor emerged from the surrounding mammals and set out upon his amazing career of development. What was the nature of the world in which he found himself? What was the environment in which he had to live and struggle and fashion his tools and weapons? What were the animals around him which he tried to conquer? What plants and trees were the outstanding features of his forests? Knowing the importance of environment in all evolution, we realize that these questions must be answered, so far as possible, if we are to understand the story of the forerunners of primitive man.

Let us first consider Pliocene Europe as it was just before the advent of man. Looking at the chart, to which we have so often referred, we note that the close of Pliocene time came approximately five hundred thousand years ago. Yet if we could view the forests of central France and northern Italy of that age we would find ourselves gazing upon familiar sights. In northern France we would discover the ancestors of the modern European forests: the oak,

the beech, the poplar, the willow, and the larch. We would note, too, trees common in our present-day American forests: here a locust, there the sumach, the bald cypress, and the tulip. In northern Italy we would come upon other old friends in the shape of the sweet gum, the sour gum, and the bay-tree; and travelling southward, we would find trees native to a more tropical climate flourishing along the shores of the Mediterranean: the bamboo and the sabal palm, the dwarf fan-palm and the sequoia.

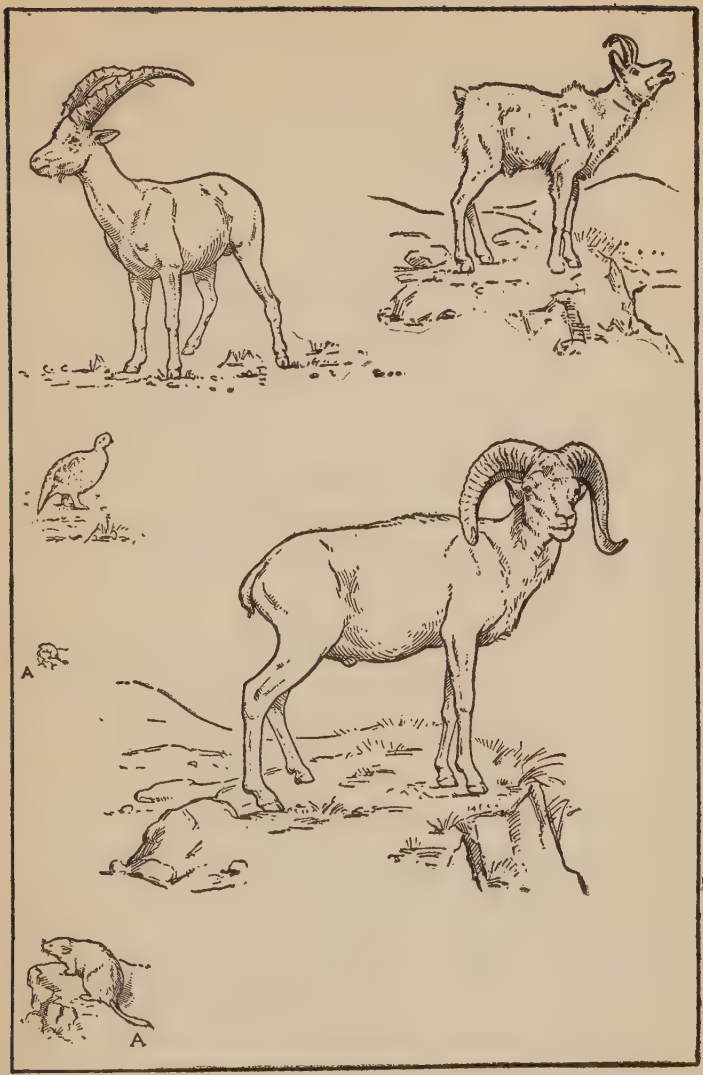
Among the mammals of Pliocene Europe we find many that had probably migrated at some distant date from North America and, more recently, from southern Asia and Africa. Thus we find primitive horses and tapirs, felines, bears, and wolves, all similar to northern Asiatic types, rhinoceroses, mastodons and elephants, gazelles and antelopes. Roaming about beneath the trees were the sabre-tooth tigers and other fierce members of the cat family; while in the branches chattered south Asiatic and north African monkeys. Most notable of all as a representative African-Asiatic animal was the river-dwelling hippopotamus, which came to Italy in early Pliocene time and made its way southward into Africa and India by means of the Sicilian land bridge which then existed. These animals, the ancestors of what we call the African-Asiatic mammal group of



Two giant quadrupeds of the close of the Old Stone Age. Above, the woolly rhinoceros; below, the woolly mammoth. The mammoth is frequently depicted by the Magdalenian artists.

Pleistocene times, all arrived in Europe before the Pliocene period was very old; but they were to be followed in middle and late Pliocene times by even more important mammals, which may be divided into three general groups: the true horses, which had probably originated at a distant date in North America; the true cattle, whose rise may be traced to southern Asia; and the true elephants, which were also of Asiatic origin.

These African-Asiatic animals were to be found in the forests and along the rivers of northern Italy in Upper Pliocene times; but by the close of the Pliocene epoch a number of the African types, such as the gazelles, antelopes, and primitive horses, had begun to disappear from Europe, due to the climatic changes which that continent was undergoing. Gradually western Europe was becoming damper, with a consequent flowering of luxuriant forests and meadows that furnished an ideal feeding-ground for cattle, deer, horses, and elephants. This, however, was only the beginning of a great climatic change which was to culminate in a glacial period affecting Europe, Asia, and America. We may trace the gradual lowering of the European temperature by the southward march of apes and monkeys, which fled before the icy terror that was laying hold of the forests in which they had lived contentedly. In Upper Miocene time



Alpine type of mammals and birds which descended from the mountains to the plains during the cold glacial periods of the Old Stone Age; the ibex, the chamois, the ptarmigan, the argali sheep, and the vole (*A*, to scale and enlarged).

the gibbon is found in northern Germany; in Lower Pliocene the apes and monkeys have already retreated to southern France; and toward the close of the Pliocene epoch they are found no farther north than the forests of upper Italy.

But the retreat of the monkeys was not shared by many other forms of mammalian life, and the late Pliocene was characterized by exceptionally close geographic relations with the Far East, by means of the Sicilian land bridge and the isthmus of the Dardanelles, which permitted the arrival of new immigrants from the Orient. Among these pilgrims, we have strong reasons to believe, were the most primitive men.

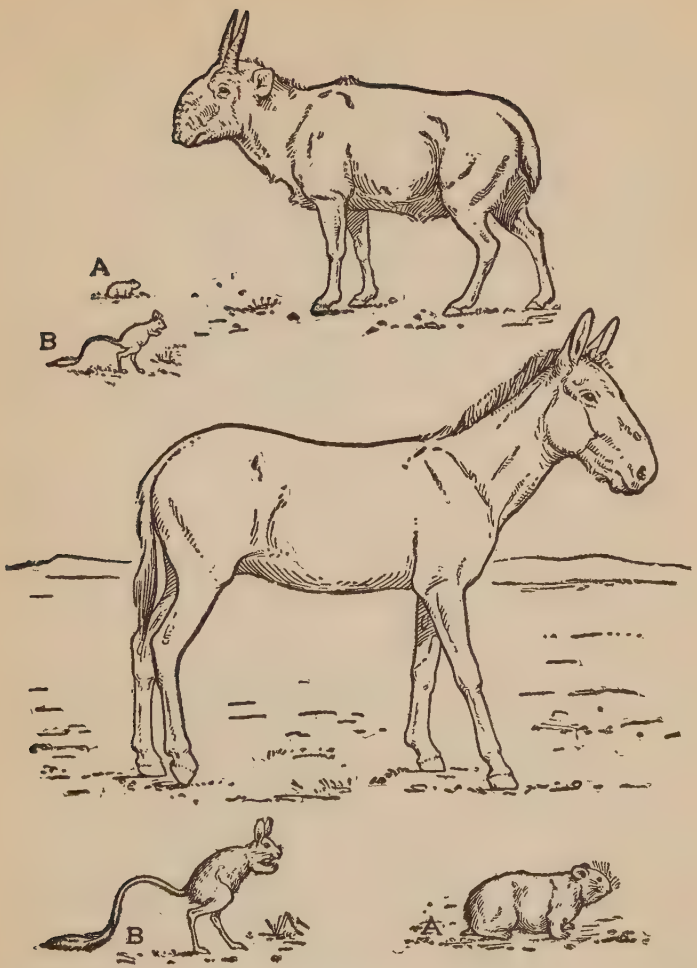
This would place the arrival of man in Europe just before the first ice age of the Pleistocene. The first harbingers of this glacial period were cold marine currents from the north which began to flow against the southwestern coast of England with a consequent lowering of temperature. At this time Great Britain apparently escaped a glacial formation of any extent, but great ice-sheets formed in North America, west of Hudson Bay, and from there they slid southward as far as Nebraska and Iowa. At the same time extensive glaciers were formed in Scandinavia, northern Germany, and the Swiss Alps. In the Alps, for example, we know that the snow-line was some 4,000 feet below its present level.

Typical mammals of the cold northern tundras which migrated southward into Eurasia during the final cave period of the Old Stone Age: the wolverene, the barren-ground reindeer, frequently depicted by the Magdalenian artists, the Arctic fox, the musk-ox, and the banded lemming (*A*, to scale and enlarged).

Naturally this vast climatic change affected the plant and animal life of Europe: the forests were modernized, while the monkeys and other animals beat a retreat from the advancing ice. But the majority of the Upper Pliocene mammals continued to exist in the vicinity of their old homes, which would indicate that regions immediately surrounding the southern borders of the ice-fields remained habitable for these various animals. The anthropoid apes, the tapir, and the mastodon vanished from the south European forests; but it was these forests which suffered the greatest extinction during the first cold wave and glaciation. Many types of trees previously common to Europe and America during Pliocene times disappeared utterly.

At the same time new animal arrivals from the north of Asia were introducing fresh elements into the living scene. From this region came the stag, the deer, and the moose; and by their sides we find such flesh-eaters as the otter, the bear, the wolf, the fox, and the marten, in company with a ferocious type of wild boar. The Oriental or south-Asiatic element made itself felt in the shape of elephants, rhinoceroses, and hippopotami, to which company two new representatives of the grassy plains were added in the early Pleistocene: the first wild cattle and the first bison.

The existence of land routes of communication be-

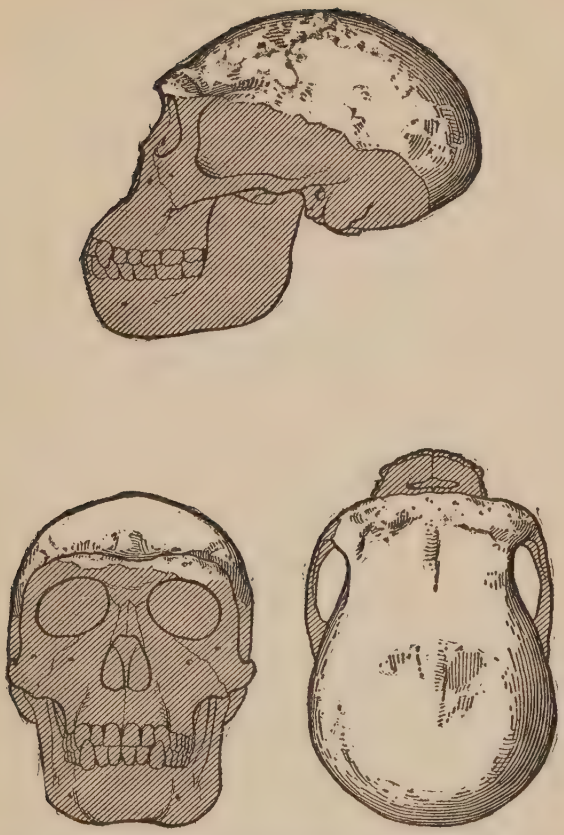


Mammals from the cold northern Steppes of central Asia which invaded Eurasia during the cold glacial period of the closing Stone Age: the saiga antelope, the kiang or Asiatic wild ass, the steppe hamster (*A*, to scale and enlarged), and the great jerboa (*B*, to scale and enlarged). The two larger mammals are quite frequently depicted by the Magdalenian artists.

tween Europe and the East is amply demonstrated by the records of mammalian life which we have discovered. Great throngs of animals swept from east to west, and preying upon the defenseless ones were the fierce sabre-toothed tigers that ranged from Europe into Asia and America.

Our chief interest in these *land routes of the mammals* is that we have reason to believe that they also served as *pathways for primitive man* on his march out of the East into Europe.

In view of these routes, the discovery in central Java of a race related to primitive man in the midst of animal vestiges remotely related to the mammalian life of southern Asia has a significance which it would not otherwise possess. The *Pithecanthropus erectus* (upright ape-man) was discovered by a Dutch army surgeon, Eugèn Dubois, near Trinil in central Java, in 1891. The fossils consisted of two molar teeth, the top of a skull, and a left thigh-bone. From these remains it has proved possible to study the brain, the top of the skull, and the thigh-bone of this ape-man, who is known to be a representative of a primitive prehuman race which we have named the *Trinil race*, from the place of its discovery. A thorough investigation of the surrounding fossil deposits has led to the conclusion that the Trinil race belonged to early Pleistocene time.



Three views of the skull of the Trinil ape-man (*Pithecanthropus*), showing the original (shaded) and restored (black lines) portions. About one-fourth actual size. *After McGregor and Osborn.*

The characteristics of the Trinil race are so close to some of the apes that many scientists at first insisted upon regarding the skull discovered by Dubois as that of an exceptionally large gibbon, while others looked upon it as a link between the prehuman and human forms. For a time controversy waxed furiously, but it is now generally admitted that the Java remains are prehuman, rather than ape-like, although they do not represent man in his most primitive stage.

Of the true fossil men of the Old Stone Age we now possess a variety of skulls and jaws that have been found in various parts of Europe, which are considered representative of various races that we have named after the places in which the remains have been discovered. England, France, Belgium, and Germany have all yielded their primitive human treasures, and from the study of bones and flints we may trace the march of man from primitive darkness toward the dawn of a social life. Speaking generally, these men of the early Old Stone Age were powerful in build but not tall: the Neanderthals, for example, stood about five feet three inches high. A low, retreating forehead gave evidence of a brain in which the intelligence was very limited but which had the sensory centres well developed. A thick coat of hair protected a body that was still only partially clothed. Weapons were of the most primitive variety—rough

flints to which no handles had as yet been attached. Society had not as yet developed beyond the primitive family group, and the chief preoccupations of existence were the fight for life and the fight for food. The earliest fossil jaws that we possess, such as the Heidelberg jaw and the Neanderthal jaw, indicate that their possessors were incapable of an articulate interchange of ideas; speech, one of the great elements of progress, was to develop later.

A summary of these fossil prehuman and human races has recently been given by Professor Osborn as follows:

"Here is the table of known fossil ancestors of man in descending geologic order:

"*Crô-Magnon Race.*—Large brain, full brow, prominent chin; existing 25,000–40,000 years ago. Second type of cave man of upper Pleistocene age.

"*Neanderthal and Heidelberg Race.*—Low brow, inferior brain, retreating chin; existing 40,000–250,000 years ago. First type of cave man was of the Neanderthal race of lower Pleistocence age.

"*Piltdown Race* (*Eoanthropus*).—Flat brow, small brain, no chin prominence; existing 500,000 years ago, or near the beginning of the Age of Man.

"*Trinil Race* (*Pithecanthropus erectus*).—Extremely low brow, smaller brain, probably retreating chin, straight thigh-bone. Very primitive side branch of

human race nearly contemporary in age with the Piltdown; not an anthropoid.

"*Foxhall Race.*—Bony remains still unknown; possibly similar in head structure to Piltdown of upper Pliocene age."

GEOLOGIC PERIOD	RACE	CULTURES
	AZILIAN and TARDENOISIAN RACE from Eurasiatic and Mediterranean regions replace Crô-Magnon Race	Azilian Tardenoisian
Pleistocene	CRÔ-MAGNON RACE	Magdalenian Solutrean Aurignacian
Pleistocene	NEANDERTHAL and HEIDELBERG RACE	Mousterian Acheulean Chellean
Pleistocene?	PILTDOWN RACE Eoanthropus	Primitive Stone and Bone Culture
Pleistocene?	TRINIL RACE Pithecanthropus erectus	Culture not discovered
Pliocene	FOXHALL RACE	Primitive Stone Culture

In the next and final chapter we shall consider the characteristics of these various races in a little more detail.

CHAPTER X

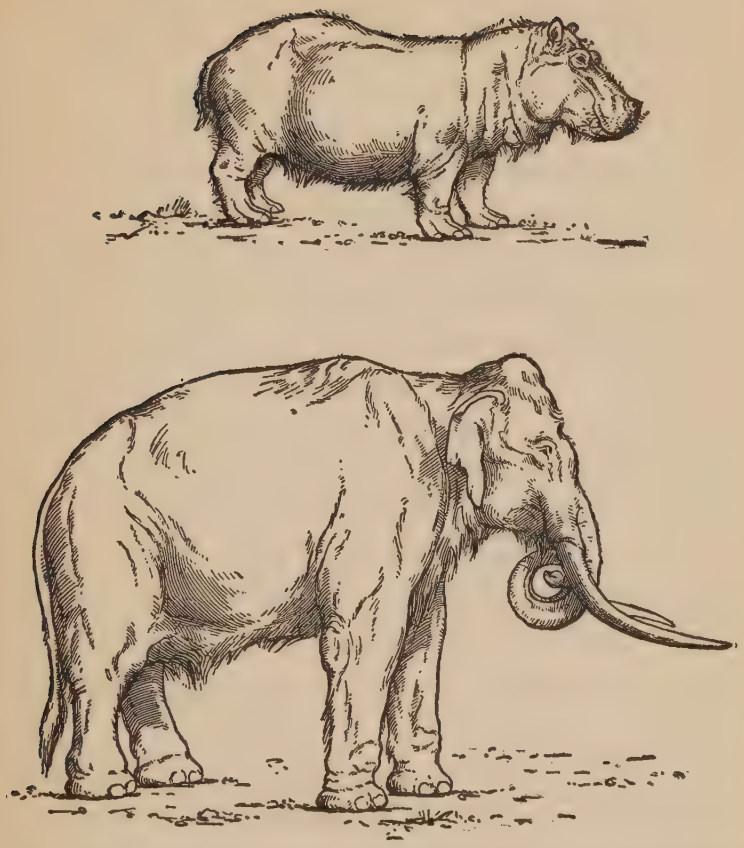
MAN

IN the preceding chapters we have seen that Evolution may not be represented accurately by a direct genealogical line in which every life form is either ancestral to, or derivitive from, some other life form. Rather, it must be pictured as a tree, constantly giving off fresh branches, some of which terminate their lives abruptly, while others branch outward and onward with ever-increasing variation and vigor. We have seen, for example, that there is no direct relationship of ascent or descent between the small Egyptian monkeys of the Oligocene Age and the modern Asiatic gibbons. Each represents a line of descent from some unknown ancestral stock of the Old World primates, from which man himself is presumably another offshoot. It has been made clear that man is descended, so far as we know, from no species of apes or monkeys with which we are familiar. He and the gibbons, the gorillas, the chimpanzees, and the orang-outangs may all trace their pedigrees back to a common ancestor. Of that we are reasonably sure, but more exact knowledge we cannot claim.

So, too, we find that there are further branchings of the human line, or Hominidæ,* even after it has diverged definitely from the anthropoid ape line, or Simiidæ.† In many parts of the world we have found the remains of man-like apes and primitive men who must be considered the distant cousins, several times removed, of modern man, rather than his ancestors. We recognize one of these cousins in *Pithecanthropus erectus*, the discovery of whose remains at Trinil, in Java, has been previously described. This creature—whose Latin name means "the erectly walking ape-man"—possessed a brain capacity about half-way between that of a typical modern man and a chimpanzee, and was notably underdeveloped in the front part of the cerebral region, wherein modern psychology has located the faculty of attention and control. His thigh-bone shows that he was well equipped for an upright position either in walking or running, and that his hands were therefore free for grasping and other purposes. He was not a man in the full sense of the word, but Sir Arthur Keith asserts that he was "human in stature, human in gait, human in all his parts, save his brain"; and it is certain that

* A family including only the relatives of man, the actual ancestors of the existing races of man and the side branches of the human race, such as the Piltdown, the Trinil, and the Neanderthal, which have become entirely extinct.

† A family including the existing anthropoid apes (the gibbon, orang-outang, chimpanzee, and gorilla) and their extinct relatives.



Great quadrupeds of the beginning of the Old Stone Age. Above, the woolly hippopotamus (*Hippopotamus major*) of western Europe; below, the southern elephant (*Elephas meridionalis*). Remains of both are found in the river-drifts of France and Spain mingled with the flints of the Chellean and Acheulean cultures. *After Osborn.*

his remains represent one of the earliest specimens of the human stock with which we are familiar. That *Pithecanthropus* belonged to a side branch of the main line from which modern man is descended, we are fairly sure; but his relationship with ourselves admits of no question. H. G. Wells, in his "Outline of History," sums up the case with characteristic directness when he writes: "This little trayful of bony fragments from Trinil, on the Island of Java, is, at present, apart from stone implements, the oldest relic of early humanity, or of the close blood-relations of early humanity, that is known."

The Java man—or "subman," if you prefer—is only one of those distant relatives of modern man whose remains have been left for our discovery and information. As we have stated earlier, *Pithecanthropus* may be assigned either to late Pliocene or to early Pleistocene time—that is, to a period that may roughly be estimated as more than half a million years ago. The next representative of "subman," in order of antiquity, is the Heidelberg man, whose remains consist solely of a massive, chinless jaw, which was discovered in the base of the "Mauer sands," near Heidelberg, at a depth of seventy-nine feet, by Schoetensack, in 1907. Professor Osborn has stated that this discovery is "one of the most important in the whole history of anthropology." As a re-

sult of it, we possess a jaw that is ape-like in general appearance, save for the teeth, which are decidedly human in structure, representing a creature that was tending toward the Neanderthal type of "subman," rather than toward *Homo sapiens*, or modern man. The evidence of the jaw shows that the Heidelberg man was not so far from the point of separation between the anthropoid and the human lines as were the men of the Neanderthal race. In comparison with the jaw itself, which is the most powerful human jaw known to us, the teeth are not very large. In his chinlessness its possessor was decidedly ape-like, and any reasonable reconstruction of him must picture a creature with powerful fore-limbs and a large, strong body, probably capable of handling the huge, rough flints that have been found in association with his remains.

According to his discoverer, the Heidelberg man belonged to the Lower Pleistocene, or First Interglacial period, about 400,000 years ago. Professor Osborn also now assigns him to the First Interglacial period. He inhabited a world in which the elephant, the rhinoceros, the horse, and the bison roamed at large, while the fierce sabre-toothed tiger was passing swiftly toward extinction. Summing up his position in the history of human evolution, Professor Osborn writes: "It would seem that in the jaw, and probably

in all other characters of the skull, as they become known, the Heidelberg race will be found to be a Neanderthal in the making, that is, a primitive, more powerful, and more ape-like ancestral form. In the matter of the retreating chin, the true Neanderthals of Spy, Malarnaud, Krapina, and La Chapelle rank almost exactly half-way between the most inferior races of recent man and the anthropoid apes." And a little later the same authority observes: "Thus, while there may be wide differences of opinion as regards the relationships of the Heidelberg man, all agree that Schoetensack's discovery affords us one of the great missing links or types in the chain of human development."

Another of the distant relatives of modern man is known to us as the Piltdown man or *Eoanthropus* (the "dawn man"), and he is of especial interest as one of the earliest human types in which the size of the brain and the shape of the skull are known. His skull, from which our knowledge of him is mostly derived, was discovered bit by bit in the region of Piltdown in Sussex, England, and was thereafter pieced together to form a convincing whole. In the same gravel bed from which the pieces of cranium had been dug up there was discovered the right half of a jaw-bone, and the problem as to whether the jaw and the skull belonged to the same individual has

Flint implements of the early Chellean culture, including primitive arrows or spear-heads, scrapers, borers, and cutters. *After Commont and Osborn.*

resulted in a long scientific controversy. Certain experts who have carefully studied the jaw would refer it to an adult chimpanzee, while the majority, including Professor Osborn and Sir Arthur Smith Woodward, are convinced that it belongs to the skull with which it was found. The precise geologic age of the Piltdown man is still questionable; but Professor Osborn tentatively assigns him to the First Interglacial times, at the same time regarding him as a side branch of the human family, ancestral to neither the Heidelberg nor the Neanderthal races. As to the brain of the "dawn man" of Piltdown, Sir Arthur Keith writes as follows:

"All the essential features of the brain of modern man are to be seen in the brain cast. There are some which must be regarded as primitive. There can be no doubt that it is built on exactly the same lines as our modern brains. A few minor alterations would make it in all respects a modern brain. . . . Although our knowledge of the human brain is limited—there are large areas to which we can assign no definite function—we may rest assured that a brain which was shaped in a mould so similar to our own was one which responded to the outside world as ours does. Piltdown man saw, heard, felt, thought, and dreamt much as we do still."

Coming to Neanderthal man we encounter a race

that has left its remains in many portions of Europe, for the fragmentary bones of this people have been discovered in Spain, France, Belgium, Germany, Czecho-Slovakia, and elsewhere. In his breezy way, H. G. Wells speaks of *Homo neanderthalensis* (to give him his full resounding Latin name) as "a quite passable human being," and in the following passage Professor J. Arthur Thomson brings him vividly before our eyes.

"He was a loose-limbed fellow," writes Thomson, "short of stature and of slouching gait, but a skilful artificer, fashioning beautifully worked flints with a characteristic style. He used fire; he buried his dead reverently and furnished them with an outfit for a long journey into the beyond; and he had a big brain. But he had great beetling ape-like eyebrow ridges and massive jaws, and he showed 'simian characters swarming in the details of his structure.' In most of the points in which he differs from modern man he approaches the anthropoid apes, and he must be regarded as a low type of man off the main line. Huxley regarded the Neanderthal man as a low form of the modern type, but expert opinion seems to agree rather with the view maintained in 1864 by Professor William King, of Galway, that the Neanderthal man represents a distinct species off the main line of ascent. He disappeared with apparent suddenness (like

some aboriginal races to-day) about the end of the Fourth Great Ice Age; but there is evidence that before he ceased to be there had emerged a successor rather than a descendant—the modern man."

The skull of the Neanderthal man was well above the average size of man's to-day, but it was low, and the most important portions—the cerebral hemispheres—were comparatively small. His teeth would indicate that he subsisted in large measure upon a coarse vegetarian diet, but we also have evidence that he was a great hunter, for in the caves that he inhabited we have found the bones of many animals, including those of the woolly mammoth, the rhinoceros, the bison, the wild horse, cattle, the giant deer, and the reindeer.

To Obermaier we owe much information regarding the probable life of Neanderthal man. The caves in which he dwelt had served previously as lairs for beasts and birds of prey. It is possible that fire was the means employed by the Neanderthals to wrest these habitations from their more primitive and ferocious occupants, but whatever the means employed, the homes thus won were characterized by decided disadvantages. During the wet seasons they were practically untenantable by reason of the moisture that seeped through the limestone roofs, and many of the bones that are left to us show that both men and animals perished from afflictions caused by

Acheulean flints described as *coups de poing*, of varied shapes (the oval, the pointed, the almond, the triangular, the disc-shaped), including some "miniature" forms. The late Acheulean is distinguished by an advance in all the finer and smaller implements, tools, and weapons; yet the finest work of Acheulean times appears thick and clumsy when contrasted with the best Solutrean work of the Upper Palæolithic. One-fourth actual size. *After De Mortillet.*

extreme dampness. Such caves as were unprovided with a hole in the roof, that might serve as a primitive chimney, were unsuited to be real dwelling-places and could be employed only as temporary retreats that might be defended with comparative ease against an enemy. The caves that were equipped with smoke vents offered a permanent shelter from cold and rain, and we have ample evidence that the men of the Neanderthal race made good use of these caverns.

Much of their time, we know, was spent in the chase; and they utilized both the flesh and the pelts of their prey, splitting the larger bones that they might suck the marrow from them. Their weapons were mainly darts and spears that were fitted with sharp flint points, and it is possible that they made use of pits for the entrapping of animals, and almost certain that they brought down some of their victims by means of suitable stones that they hurled with deadly accuracy; but the bow and arrow were apparently unknown to them. As soon as an animal was brought down it was immediately dismembered upon the spot where it had fallen: the brain was removed from the skull, the long bones were split open for the marrow, and the pelts were dragged back to the community caverns so that the women of the race might fashion them into clothes and coverings.

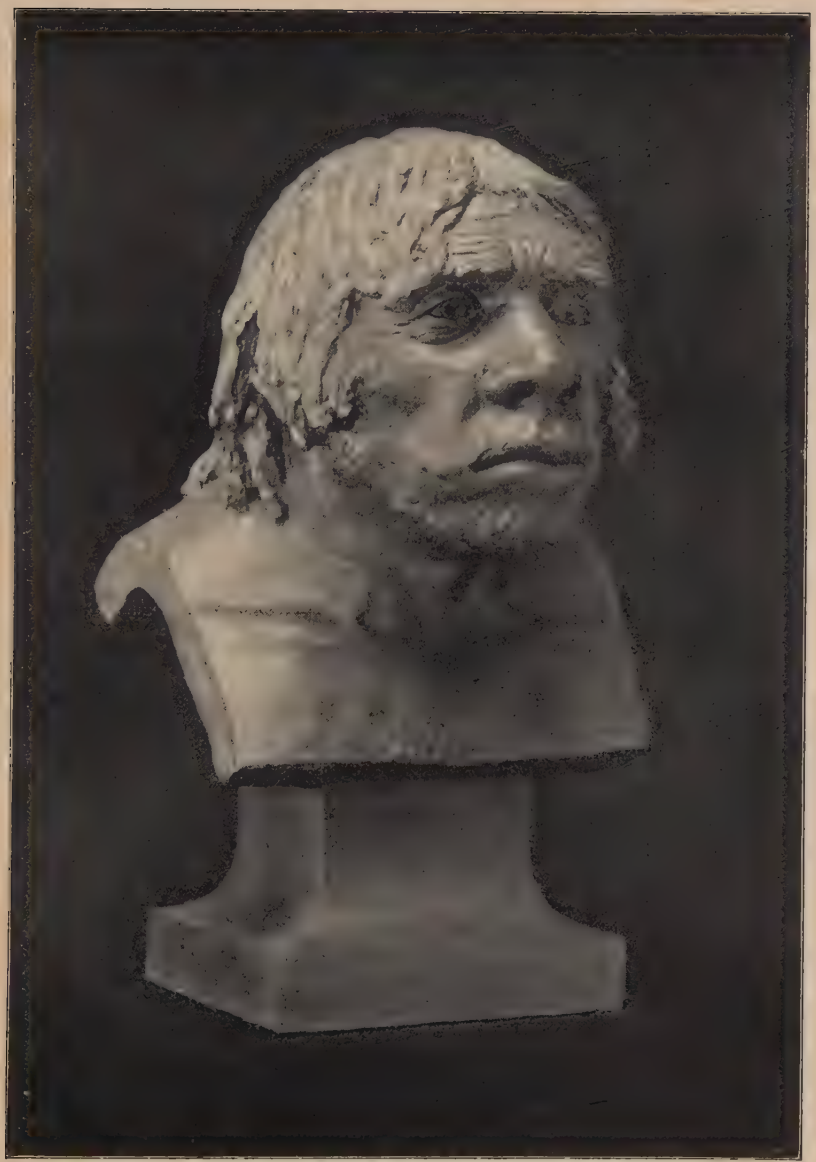
From the above it is obvious that we know a good

deal concerning the anatomy, brain, and habits of Neanderthal man. We know, as the result of long study, that his skull, despite his proven brain capacity and abilities, was in many characteristics nearer that of the anthropoid apes than to that of *Homo sapiens*, or modern man. It may be well to quote, as supplementary to the description given by Sir Arthur Keith, a passage by Professor Osborn, in which he gives us a rather more precise anatomical description of the creature under consideration. Professor Osborn writes:

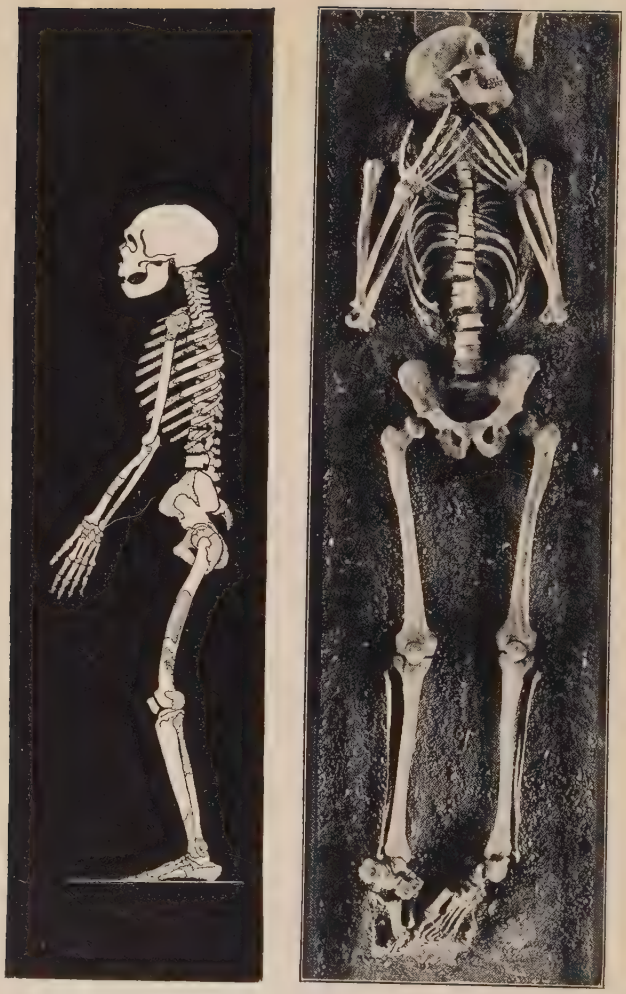
"The total aspect of Neanderthal man may be characterized in the following manner: An enormous head placed upon a short and thick trunk, with limbs very short and thickset, and very robust; the shoulders broad and stooping, with the head and neck habitually bent forward into the same curvature as the back; the arms relatively short as compared with the legs; the lower leg, as compared with the upper leg, shorter than in any of the existing races of men; the knee habitually bent forward without the power of straightening the joint or of standing fully erect; the hands extremely large and without the delicate play between the thumb and fingers characteristic of modern races; the resort to a squatting position while occupied in flint-making and other industries. Thus the ordinary attitudes of *Homo nean-*

derthalensis would be quite different from our own and most ungainly. The heavy head, the enormous development of the face, and the backward position of the foramen magnum, through which the spinal cord connects with the brain, would tend to throw the upper part of the body forward, and this tendency, with the lesser curvature of the neck, the heavy shoulders, and the flattened form of the head, would give this portion of the body a more or less anthropoid aspect."

All this information that we possess regarding the Neanderthals we owe to a series of discoveries beginning with a skull that was found by Lieutenant Flint on the north face of the Rock of Gibraltar in 1848. Since then more than twenty separate discoveries of Neanderthal remains have been made in various parts of Europe, ranging in importance from a single milk-tooth, found near Weimar, Germany, to an almost complete skull and skeleton that were unearthed in 1909 at Corrèze, France. Regarding some of these remains there is doubt that they belong properly to the Neanderthal species, and to these we refer as "Neanderthaloid." This doubt, indeed, was soon cast upon the Gibraltar skull itself, the first discovery of all, and a number of eminent authorities, including Keith, contend that it is the most ape-like of all human fossils and should definitely be classed as pre-



Restoration of low-browed Neanderthal man discovered in the cavern of La Chapelle-aux-Saints in central France. *After McGregor and Osborn.*



Comparative view of the skeleton of Neanderthal man (left) from the cavern of La Chapelle-aux-Saints and of the skeleton of a very tall member of the Cro-Magnon race (right) from the Grotte des Enfants, Monaco. Figures approximately one-seventeenth life size. *After Boule, Verneau, and Osborn.*

Neanderthaloid. Other scientists, however, affirm that it is of the same geologic age as the skulls since discovered in other portions of Europe. Whatever the truth of the matter may be, we have ample relics upon which to base our opinion of this remarkable race that hunted, loved, and flourished during the fourth and last glacial epoch.

The Neanderthal remains that we possess are so varied in the development of head forms and teeth that we know they represent an evolution from lower to higher types that must have required many thousands of years. Certain scientists go so far as to maintain that the Neanderthals advanced so far as partially to evolve into the lower races of *Homo sapiens*, or modern man; but another view, supported by Professor Osborn among others, is that they represent an offshoot from the main line of human descent, and that they suffered complete extinction in western Europe.

Professor Osborn sums up his view of the case in the following succinct paragraphs:

"Whatever may have been their fate in other regions, certainly the most sudden racial change which we know of in the whole prehistory of western Europe is the disappearance of the Neanderthal race at the close of the Mousterian culture stage, which was the latest industrial period of Lower Palæolithic times,

and their replacement by the Crô-Magnon race. From geologic evidence the date of this replacement is believed to have been between 20,000 and 25,000 years before our era. So far as we know at present, the Neanderthals were entirely eliminated; no trace of the survival of the pure Neanderthal type has been found in any of the Upper Palæolithic burial sites; nor have the alleged instances of the survival of the Neanderthal strain or of people bearing the Neanderthal cranial characters been substantiated. We incline to agree with Boule and Schwalbe that the supposed cases among modern races of the transmission of Neanderthal characters are simply low or reversional types, which, upon close analysis, are never found to present the highly distinctive and peculiar combination of Neanderthal characteristics.

"There is some reason to believe that the Neanderthals were degenerating physically and industrially during the very severe conditions of life of the fourth glaciation, but the consequent inferiority and diminution in numbers would not account for their total extinction, and we are inclined to attribute this to the entrance into the whole Neanderthal country of western Europe toward the close of Lower Palæolithic times of a new and highly superior race. Archæologists find traces of a new culture and industry in certain Mousterian stations preceding the disappearance

Left.—Flint implements of advanced Mousterian age fashioned by the Neanderthal flint-workers; arrow points, double-ended arrow points, scrapers, double scrapers. One-fourth actual size. *After De Mortillet.*

Right.—Mousterian arrow "points," scrapers, and arrow-shaped fasteners, from Suffolk, England, Umbria, Italy, the Crimea, Russia, and Dordogne, France. One-fourth actual size. *After De Mortillet.*

of the typical Mousterian industry. Such a mingling is found in the valley of the Somme in northern France.

"From this scanty evidence we may infer that the new race competed for a time with the Neanderthals before they dispossessed them of their principal stations and drove them out of the country or killed them in battle. The Neanderthals, no doubt, fought with wooden weapons and with the stone-headed dart and spear, but there is no evidence that they possessed the bow and arrow. There is, on the contrary, some possibility that the newly arriving Crô-Magnon race may have been familiar with the bow and arrow, for a barbed arrow or spear head appears in drawings of a later stage of Crô-Magnon history, the so-called Magdalenian. It is thus possible, though very far from being demonstrated, that when the Crô-Magnons entered western Europe from central Europe, at the dawn of the Upper Palæolithic, they were armed with weapons which, with their superior intelligence and physique, would have given them a very great advantage in contest with the Neanderthals."

It is impossible for us to reconstruct the struggle that probably took place between the old subhuman race and the more highly gifted and equipped newcomers; indeed it may be that there was actually no conflict between them, and that the evidence we pos-

sess is misleading; but whether there was a struggle or not, we know that the old cave-dwellers of western

Flint and bone implements of Aurignacian age. The finely pointed flint implements (left) were used in fine engraving and etching on stone or bone by the artists of the period. The pointed bone implement (right) was probably used in the chase. *After Obermaier and Osborn.*

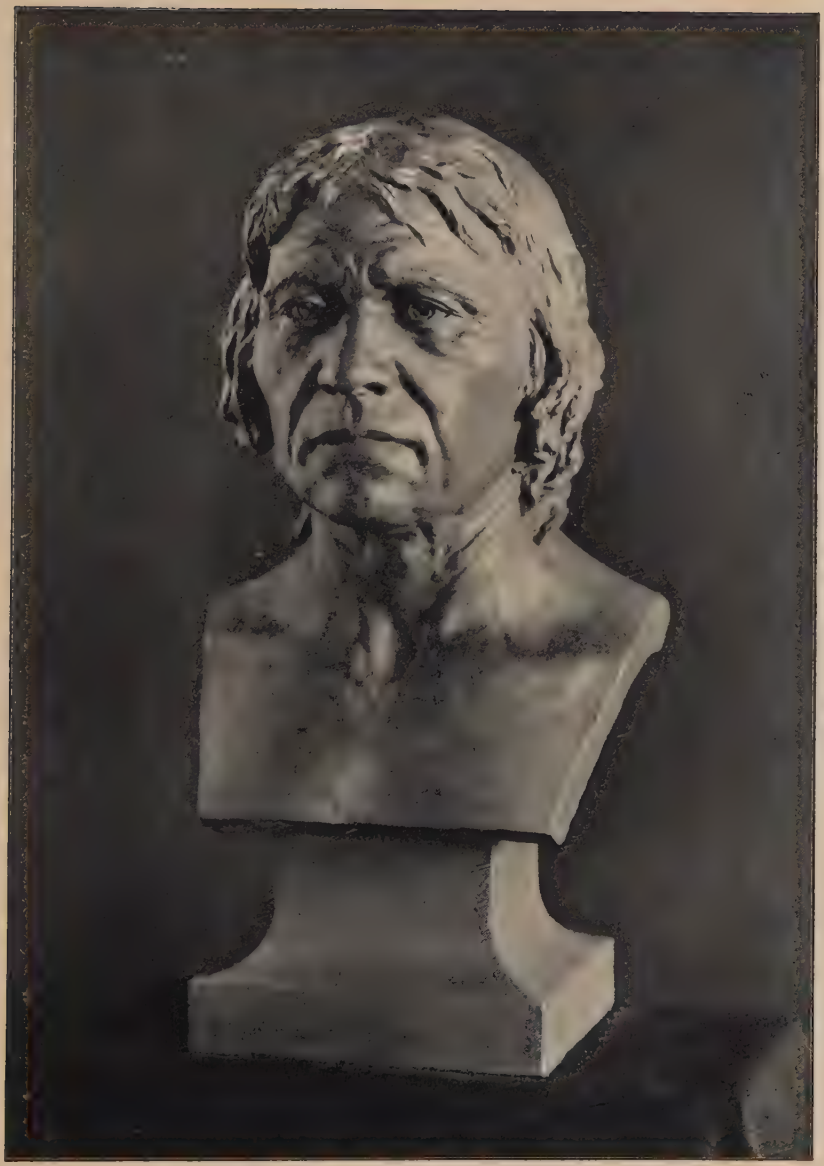
Europe, who had driven the beasts and the birds from their lairs, yielded up their habitations in turn to a people who were sufficiently developed to decorate their caves with remarkable drawings of the beasts they knew. A new era had dawned, a new kind of beings had arrived; there had occurred what has

properly been termed the most profound change in the whole racial history of western Europe.

Who were these folk, then, with their great bodies and their fine brows, who displaced the Neanderthals? They have been named after the place in which the best examples of their skeletons were found, the little village of Crô-Magnon, in Perigord, France. They are known to the world of science as the Crô-Magnon race; but we may give them a simpler name. They were the first true men, the first undoubted representatives of *Homo sapiens*, of man as we know him.

They were a tall race: we find that the skeleton of an old man is rather more than six feet four inches, and that of a woman is just five feet five inches. The receding brow of the Neanderthals is notably absent, and the Crô-Magnon man is distinguished by the possession of a firm, strong chin—sure sign of the modern type

The first specimen of this race was discovered in a Welsh cave by Buckland. At the time the full significance of the skeleton he had found was not realized, but later investigators have agreed that it undoubtedly belonged to a man of the Crô-Magnon race. Later, in 1852, the fragments of some seventeen skeletons, representing both sexes and all ages, were stumbled upon by a laborer in the grotto of Aurignac, in Haute-Garonne; but these priceless relics were



Restoration of high-browed Cro-Magnon man of the upper Old Stone Age. *After McGregor and Osborn.*

One of the bisons painted in three colors on the ceiling of the famous cavern of Altamira, Spain. *After Breuil.*

promptly buried in the local cemetery, by order of the mayor, so when the scientist Lartet visited the grotto in 1860, he found it destitute of all human relics. But eight years later he was fully compensated, for in a grotto near the little village of Crô-

Single and double fishing harpoons of Magdalenian culture used by the men of the Old Stone Age. *After Breuil and Osborn.*

Magnon he came upon five skeletons that are now accepted as typical of the folk who succeeded the Neanderthals—and the little French hamlet gave its name to the great race of Upper Palæolithic times.

With the arrival of the Crô-Magnon people upon the scene of western Europe we draw to the close of our long story, briefly told, in which we have traced the chain of life from the first bacteria, grasping an existence directly from the earth and air, to men who

were highly skilled artisans and artists, great hunters, and possessed of an *intelligence* that was destined to evolve, slowly and surely, until by virtue of it the direct descendants of the Stone Age folk had created the world we know to-day. Their appearance is the first event of European prehistory to which we may, with considerable confidence, assign a definite date. We know that their advent was virtually simultaneous with the close of the Fourth Glacial period and the beginning of Postglacial time; and we can therefore state that true man made his appearance in western Europe between 25,000 and 30,000 years ago. What a brief time this is compared with the vast periods that we have been considering; but how much has been accomplished in this short span of years! With the Crô-Magnons, we have reached the birth of art, the birth of implement-making in higher forms than the Neanderthals ever knew—in short, we have reached the birth of an *intelligence* that may properly be called human. The brain of man had appeared upon the earth, and the modern world existed potentially in the development of that brain.

The culture of the large-brained Crô-Magnon race forms a complete art and industrial cycle, which has been traced from beginning to end by a succession of French archæologists. When this culture reached its climax it suddenly disappeared and throughout all of

western Europe was replaced by two closely related but greatly inferior cultures known in the north as the *Tardenoisian* and in the south as the *Azilian.*

Four stages in the manufacture of the *hache,* or Neolithic stone axe. *A, hache* of flint, roughly flaked into shape, from Olendon, Calvados. *B, hache* of flint ready for polishing, from Oise. It has been finely chipped to a shape of perfect symmetry, with especial care to smooth out and reduce the large facets made by the preliminary flaking. *C, hache* of flint after the first polishing, from Abbeville on the Somme. The cutting edge has been completely polished but along the sides the facets made by flaking are plainly visible. *D, hache* of flint completely polished, from Le Vesinet, Seine-et-Oise. In this last stage one scarcely notices the faint traces of facets which show that this *hache* has passed through all the preceding stages. Two-ninths actual size. *After De Mortillet.*

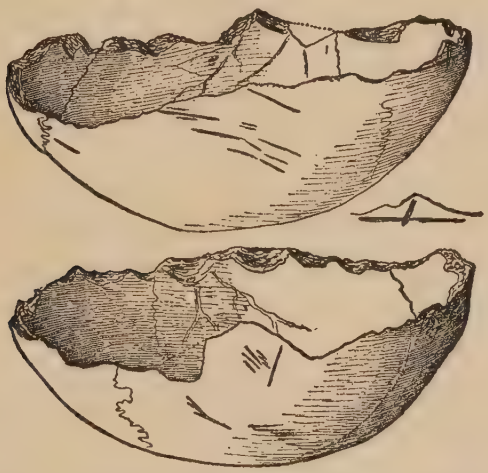
The flint implements of this culture period are exceedingly fine, and it would appear that they were used in fishing rather than in the more vigorous and manly chase of the larger mammals. If these people had any art they have left no traces of it in the caverns which they inhabited, such as the Mas d'Azil of southern France, from which the Azilian takes its

name. The most likely theory of this sudden decadence in the use of weapons and in art is that at the close of the glacial period all of western Europe became heavily forested, the great mammals of the Ice Age disappeared, and the newly migrating peoples lived along the streams and subsisted solely upon fish.

To describe the work and life of the cave men would be a fascinating task; whole volumes have been devoted to their art alone, and their racial customs are of profound interest to us, their descendants. But in a book of so brief a compass as this one such description must be foreborne. We are reduced to generalities of the barest sort. When the great ice-fields vanished from Europe, the age of Palæolithic culture was succeeded by Neolithic; rough stone implements and weapons were supplanted by arms and tools of polished stone. As yet the use of metal was unknown; but when thousands of years had passed, some genius, or geniuses, conceived the idea of working a certain malleable metal, and the Age of Copper was ushered in. Then followed the Age of Bronze, and after it the Age of Iron.

One of the oldest distinctions between civilizations is that between the use of stone and of metal for cutting tools. This difference may not be so fundamental as the contrasts in the materials imply, for there are many aspects to civilization dependent upon the use

neither of stone nor of metals. But as most of our knowledge of the past is derived from objects preserved in the ground, objects of stone and metal, because of their relative indestructibility, form the



Human skull tops cut into ceremonial or drinking-bowls, from the Magdalenian layer of Placard, Charente. *After Breuil and Obermaier.*

greater part of the evidence. They thus become time-markers for the periodic changes in man's life. When one finds in the ground traces of former habitation and observes only stone tools, it is safe to assume that the people once living there were on the level of a stone age.

The researches of archæologists in Europe and the adjacent parts of Asia and Africa have established

the following sequence of tool materials: first, stone, then copper, followed by bronze, and lastly, iron. A similar sequence has been established by students in the New World, except that no aboriginal American tribe ever reached the iron stage. Bronze was made in Mexico and in parts of South America long before Columbus made his voyages, but these old metal-workers never discovered the use of iron.

In the Old World all the metals were in use before the era of Record History, so it is difficult to set a date for the discovery of iron, but the use of iron does not begin to displace bronze in Europe until about 500 B. C., though in parts of Asia it may have come in 500 years earlier.

Copper appears in Egypt early and bronze seems to be well established before 3000 B. C., but bronze did not reach central and northern Europe until about 1900 B. C. Presumably it was first put to use by the Egyptians or one of their neighbors.

In the copper and bronze age we meet with writing, stone-masonry, the arch, the chariot, exact astronomical knowledge and calendar systems and the building of fine monuments to the dead. Many of our best known implements, as the sword, were developed in this period, to be later made of iron.

Montelius, the Swedish archæologist, states that bronzes of Scandinavian manufacture have been

found in Italy in tombs dating back to 900 B. C. By means of such discoveries he has traced the old trade routes between Sweden and the Mediterranean. In the course of thousands of years implements, symbols, and inventions—useful, religious, or artistic—slowly found their way westward and northward, from eastern Asia (the seat of earlier cultures) to Sweden. For example, copper is said to have been used at Anau, Turkestan, about 4000 B. C., and first appears in Scandinavia 1500 years later—namely, 2500 B. C. The Age of Bronze, which was in full sway in Egypt and Chaldea by 3000 B. C., makes its first appearance in Sweden 800 years later.

To Montelius and to Sophus Müller we owe masterly descriptions of the climax of the Age of Bronze in Sweden and Denmark, preceded by the climax of the Neolithic, or New Stone, Age in this low-lying northwest corner of Europe, which was the last area to be liberated from the great glaciers retreating northward to their centre in the Scandinavian highlands. This phase of Prehistory covers about fifteen thousand years and intervenes between the close of Palæolithic time and the Age of Bronze. Northwestern Europe always lagged behind southeastern Europe in its art, industry, and religion. Thus in the early Bronze Age the sun-worship of the East reached northwest France, and the wonderful

stone monuments known as *dolmens* and *menhirs*, still standing along the coast of Brittany and westward to Stonehenge, England, bear testimony to the intensity of belief in a beneficent and harvest-producing sun-god. In the Department Morbihan, southern Brittany, the famous megalithic monuments of Carnac and Locmariaquer are still to be seen. The transportation and placing of these more or less gigantic stones, or "megaliths," involved a knowledge of mechanics and of architecture, and the accuracy with which they are placed with reference to the rising of the sun testifies also to knowledge of the rudiments of astronomy.

Thus our European ancestors passed through a long Palæolithic hunting stage of evolution with only flint implements; through all the Neolithic phases; through a superb development of the arts of copper and of bronze; finally, into the culminating period of the Age of Iron.

Accordingly, when we reach the Iron Age we are in the first millennium B. C., and we leave Prehistory for Record History itself. The story of primitive man and his ancestors has been told, and the accomplishments of modern man are before us. We have followed the divergence of the great Primate stock from all other mammals; we have traced the

development of the anthropoid line and the human line from a common source; and finally we have reached the line of true human descent, from which the masters of the world were destined to evolve. The story that we have told in plain and frequently abbreviated language is the greatest of all stories, the story of The Chain of Life itself.

With the tale of the past fresh in our minds, we may confront the future, if not with accurate prevision, with, at least, keenly stimulated imaginations and an acute realization of infinite possibilities.